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THE RELATION OF CERTAIN NON-LEGUMINOUS PLANTS TO THE NITRATE CONTENT OF SOILS.

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WE have already shown [1] that at least certain of the Leguminosæ have a distinct effect upon the process of nitrification in the soils in which they grow. Their beneficial influence on nitrification may be connected with the symbiotic relation they bear to nitrogen fixing bacteria. It is conceivable that the root tubercles with their abundant supply of nitrogenous matter may by their decay, even during the life of the plant, so increase the supply of easily decomposable nitrogenous matter in the soil as to account for the increased nitrifying power of legume bearing soils. If this be the explanation for the phenomenon it marks a sharp line in the relation of legumes toward the soil in distinction from non-legumes.

Experiments that we are conducting with cereals and with other non-legumes indicate that these crops differ one from another in their relation to the occurrence of nitrates in the soil on which they grow. The nitrate content of the soil is largely dependent on the kind of crop grown. The extensive literature

[1] Journal of Industrial and Engineering Chemistry (1910), ii, 313–315.

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bearing on the nitrate content of soils contains a number of instances illustrating this relationship between the soil and the crop growing on it, but in no case has any particular significance been attached to it.

Deherain [2] found a greater loss of nitrates from the soils growing peas and clover than from those with grain crops in the drainage of the soil tanks at Grignon. He accounts for this through the inability of the legumes to take up nitrates as readily as do the graminaceous plants.

Webbel [3] took soils from fields in which the character of the soil was similar, but in which the crops were different. These were placed in lysimeters. While in the lysimeters no crops were grown in the soils, but they were allowed to leach; the drainage being collected and analyzed.

Soil was taken from fallow land, wheat land and alfalfa land. The soils were kept in lysimeters from Nov., 1904 to Oct., 1906. The nitrates expressed in grammes HNO_3 per square metre surface amounted to 40 Gm. from the fallow land and 48 Gm. from the wheat land in the lysimeters 25 cm. deep and 66 Gm. from the fallow land, 77 Gm. from the wheat land and 78 Gm. from alfalfa land in lysimeters 50 cm. deep. With Ebermeyer lysimeters, which are funnels placed under a column of soil in the field by hollowing out the soil under the column, they also obtained more nitrates in the drainage from wheat soil than from fallow land, both where the column of soil was 25 cm. deep and where it was 50 cm. deep.

King and Whitson [4] report an experiment in which one of the two contiguous plats of oats had a crop entirely removed on June 20, on which date determinations of nitrates were made in the soil of both plats to a depth of four feet. The crop on the harvested plat was weighed and dry matter determined. At the end of nineteen days nitrates were again determined in both plats and the remaining oats were harvested, weighed and dry matter determined. No determinations of nitrogen were made in the crop, but the gain in nitrogen for the nineteen days was calculated from the dry weight on the basis of average analyses

[2] Ann. Agron. (1891), xvii, 49–82.

[3] Report of the Chem. Lab. of the Ploty Experiment Station for 1905.

[4] Wisconsin Sta. Bulletin No. 93.

for oat plants at that stage. The gain in nitrogen in the oat plants growing for the 19 days minus the loss of nitrates during that time was twice as great as could be accounted for by the gain of nitrates on the bare plat. No account was taken of the nitrogen in the plant roots which would make a still greater difference. The authors suggest that the discrepancy may have been due to failure to obtain all of the nitrates from the soil in the process of analysis. While an error of this kind doubtless existed it must be remembered that the results hinge on nitrate determinations on both plats which should practically neutralize this error.

Similar results with clover were obtained by the same investigators, but being a legume this may be accounted for by processes already understood.

The same investigators [5] determined nitrates in soils to a depth of four feet under corn, potatoes, alfalfa and clover.

As between the cultivated crops corn and potatoes there was a fairly definite relation, the nitrates being higher under the corn. The soil under the non-cultivated crops was naturally lower in nitrates.

Stewart and Greaves [6] in a study of nitrates in irrigated soils planted to corn, potatoes and alfalfa and also on fallow land during a period of three years, and oats one year give figures that show nitrates to be higher under corn than under potatoes and considerably lower under alfalfa and oats. The fallow frequently contained less nitrates than corn land and sometimes less than potato land. They also found that there was a steady loss of nitrates in corn and potato soil after the growing period had ceased while fallow plats similarly cultivated did not show nearly as large a loss. Alfalfa land maintained an almost constant nitrate content throughout the year while corn and potato land showed a decline.

SIGNIFICANCE OF EXPERIMENTS CITED.

The bearing which these results have on the hypotheses presented in this paper is to be found in the occurrence of nitrates in soil under crops in excess of those in similar soil

[5] Wisconsin Sta. Bulletin Nos. 85 and 93.

[6] Utah Agricultural Experiment Station Bulletin No. 106.

uncropped, and in the drainage water of previously cropped soil in greater quantity than in drainage water from similar soil previously in fallow. These phenomena raise the question as to what relation certain plants may have to nitrates either in their production or removal. The more or less definite relation in any one soil between the kind of crop and the quantity of nitrates under it leads to the question whether this relationship differs with different plants.

INVESTIGATIONS AT THIS STATION.

In 1907, 1908, and 1909 determinations of nitrates were made in field plats under timothy, corn and oats in rotation the results of which led us to investigate further the relation of the plant to the nitrate content of the soil. The earlier determinations were from samples of soil taken to a depth of only eight inches, but later samples were taken of each foot of soil to a depth of four feet.

EXPERIMENTS ON PLATS MANURED FOR TIMOTHY.

Experiment plats each one-tenth acre in size were used in this experiment. They were in rotation of timothy three years, corn, oats, and wheat each one year, and had been fertilized in different ways for timothy, but received no fertilizer for the grain crops which followed. There were twenty-two plats in all. Their treatment is shown in Table I.

On these plats samples of soil were taken to a depth of eight inches at intervals during the growing season and after the timothy and oats had been removed. The entire twenty-two plats were sampled on the same day or on two contiguous days. The samples were removed from the earth by means of a soil auger. Twelve borings were removed from each plat. These were thoroughly mixed on an oilcloth surface and a pint sample placed in a glass jar. The sample was brought to the laboratory and moisture and nitrates determined, the former by drying to constant weight at the temperature of boiling water, and the latter by the phenoldisulphonic acid method, comparisons with a standard nitrate solution being made by means of the colorimeter designed by Schreiner.

In 1908 and 1909 when the plats were planted to corn and oats respectively, an unplanted space was left for twenty-five

feet on the north end of each plat. This unplanted space was cultivated when the plats were in corn, receiving the same cultivation as did the planted portion of the plat. When the

TABLE I.

CROP ROTATION AND FERTILIZER TREATMENT OF PLATS MANURED FOR TIMOTHY.

Plat No.	Fertilizer treatment per acre in 1905–1907. Crop, timothy	Corn, 1908	Oats, 1909
711	No fertilizer	No fertilizer or manure applied	No fertilizer or manure applied
712	320 lbs. rock superphosphate		
713	80 lbs. muriate of potash		
714	No fertilizer		
715	160 lbs. nitrate of soda		
716	320 lbs. rock superphosphate 160 lbs. nitrate of soda		
717	No fertilizer		
718	320 lbs. rock superphosphate 80 lbs. muriate of potash		
719	160 lbs. nitrate of soda 80 lbs. muriate of potash		
720	No fertilizer		
721	160 lbs. nitrate of soda 80 lbs. muriate of potash 320 lbs. rock superphosphate		
722	160 lbs. nitrate of soda 80 lbs. muriate of potash 640 lbs. rock superphosphate		
723	No fertilizer		
724	320 lbs. nitrate of soda 80 lbs. muriate of potash 640 lbs. rock superphosphate		
725	320 lbs. nitrate of soda 80 lbs. muriate of potash 320 lbs. rock superphosphate		
726	No fertilizer		
727	320 lbs. nitrate of soda 80 lbs. muriate of potash 320 lbs. rock superphosphate		
728	640 lbs. nitrate of soda 80 lbs. muriate of potash 320 lbs. rock superphosphate		
729	No fertilizer		
730	No fertilizer		
731	1905, 10 tons manure applied; 1906, no manure; 1907, 10 tons manure		
732	1905, 20 tons manure applied; 1906, no manure; 1907, 20 tons manure		

plats were in oats the unplanted space was kept free from weeds by scraping with a hoe. Soil samples were taken from the planted and unplanted portions of each plat on the same dates,

which permits of a comparison of the effect of a certain soil treatment on the uncropped as well as on the cropped soil. It also serves to show the relation of the crop to the nitrates in the soil naturally a very important factor in their occurrence.

Table II contains a statement of the nitrate content of each plat on the dates sampled during the three years. At the foot of the table is the average for all plats on the dates analyzed, and below that is the average for all unfertilized and unmanured plats. The last, by eliminating the effect of nitrate fertilizers, is a somewhat better index to the normal course of nitrification than is the average of all the plats.

The timothy had been on the land for two years previous to 1907 and there was a good stand. The commercial fertilizers had been added twice and the farm manure once in the two years. For the crop of 1907, farm manure was applied as a top dressing on October 2, 1906, to the plats designated in Table I and the commercial fertilizers were applied April 23–24, 1907. The samples were taken April 23, immediately before the fertilizers were applied. The timothy was cut July 23 and samples for nitrates were taken the next day. The corn was planted May 29 and cut Sept. 24. No fertilizers or manure was applied to either the corn or oats. The oats were drilled in on April 23, the day following the first sampling for nitrates. They were harvested on Aug. 6, and samples taken the following day.

SEASONAL RANGE OF NITRATES UNDER TIMOTHY, CORN, AND OATS.

A striking feature of the nitrate content of the timothy plats is the uniformity and scarcity of nitrates throughout the growing season. In all but the nitrate fertilized plats the nitrate content was higher in April and August than during the period of more active growth. The land had not been plowed for two years and was covered with a thick sod, neither of which conditions were favorable for nitrification. The season range of nitrates under the timothy resembled that under alfalfa in the experiments of King and Whitson and Stewart and Greaves. During the first half of May, when growth first became active there was a tendency for the nitrates to increase as shown by the analyses of May 3 and 14, there was then a decrease during

TABLE II.

NITRATES (NO_3, P. P. M., DRY SOIL) IN PLATS 711–732 AT CERTAIN PERIODS DURING THREE YEARS.

Plat. No.	Timothy, 1907										Corn, 1908						Oats, 1909			
	Apr. 23	May 3	May 14	May 22	May 24	June 6	June 13	June 20	July 24	Aug. 14	S M May 19	S M June 22	N M July 6	S M July 27	N M Aug. 10	Sept. 17	Apr. 22	June 24	July 12	Aug. 7
711 ch.....	4.2	4.6	1.3	1.9	3.2	3.5	4.6	3.9	5.3	7.2	25.1	40.3	62.0	182.0	162.5	...	93.8	37.8	7.6	9.8
712.....	5.0	3.3	5.2	2.6	3.9	1.9	1.8	1.2	6.5	6.0	10.3	31.5	52.9	172.0	162.5	...	61.2	14.2	6.9	3.2
713.....	11.3	2.7	4.0	2.6	4.6	2.6	2.6	1.2	5.8	8.4	14.5	40.3	58.8	172.0	201.5	...	44.2	24.7	8.6	10.5
714 ch.....	16.0	4.6	6.9	1.9	7.4	3.9	4.0	2.1	5.6	9.6	22.4	52.0	89.6	268.0	237.6	...	60.2	18.1	6.7	8.0
715.....	14.6	15.2	6.2	3.3	8.0	1.8	2.1	1.8	5.5	3.6	25.8	57.2	60.5	211.0	158.4	...	56.0	10.0	7.9	10.8
716.....	13.0	9.0	8.0	1.9	3.3	2.7	2.4	2.7	5.3	7.8	32.6	69.1	47.3	261.0	156.0	...	31.7	5.0	5.6	7.8
717 ch.....	11.4	2.0	4.0	1.6	2.0	1.7	3.3	4.5	5.0	6.0	20.1	43.5	39.0	211.0	234.0	...	45.5	16.0	2.8	2.4
718.....	6.6	1.3	2.6	1.3	2.4	1.3	1.6	2.2	3.5	3.6	11.7	36.5	39.7	224.0	140.8	...	56.7	2.6	2.5	2.0
719.....	6.0	3.3	9.9	1.3	2.4	1.4	1.0	0.9	2.1	4.2	21.4	30.2	30.5	178.0	160.0	...	66.0	19.2	2.5	2.8
720 ch.....	8.0	2.0	3.3	1.6	2.6	1.8	1.8	1.2	2.9	6.0	16.7	31.5	102.4	211.0	136.5	...	50.1	12.8	2.5	3.3
721.....	4.8	9.5	72.7	22.4	2.1	1.9	1.3	1.3	3.4	5.4	20.1	38.4	66.5	130.0	151.8	...	36.4	2.6	3.8	4.2
722.....	3.3	6.1	8.0	1.9	2.1	1.2	1.2	1.2	2.0	4.8	12.0	32.2	46.6	97.5	201.6	...	26.4	3.9	2.5	2.6
723 ch.....	5.7	4.1	4.7	0.6	2.6	1.4	1.0	1.2	3.0	1.8	11.4	47.1	44.7	141.0	198.0	...	40.2	3.9	4.5	0.8
724.....	5.0	13.7	14.1	5.2	3.9	2.4	1.3	0.9	2.4	4.2	11.6	36.5	50.4	208.0	117.0	...	30.3	3.9	4.5	1.6
725.....	10.3	34.1	37.5	4.0	2.8	2.2	1.8	1.8	9.1	6.6	21.4	50.4	56.3	194.0	105.6	...	29.7	3.3	4.9	1.2
726 ch.....	....	...	...	...	...	...	...	...	...	...	10.7	38.4	51.2	228.0	147.4	...	26.8	4.6	2.5	1.1
727.....	....	...	...	...	...	...	...	...	...	...	15.2	49.2	75.4	194.0	170.6	32.0	41.5	2.9	3.1	1.4
728.....	12.3	51.6	97.4	47.4	39.1	7.8	50.0	8.4	6.5	7.8	14.7	42.2	80.6	178.0	165.0	...	59.4	3.9	6.0	2.2
729 ch.....	....	...	...	...	...	...	...	...	...	...	4.0	24.8	100.8	158.0	178.2	49.5	45.5	21.1	3.5	1.1
730 ch.....	8.2	4.1	3.3	1.9	2.6	2.4	0.8	1.3	2.2	1.8	6.7	27.3	50.4	150.0	151.8	...	44.2	14.7	3.4	1.0
731.....	8.5	1.3	4.5	1.9	2.6	2.7	1.1	1.8	2.3	2.4	14.3	26.4	70.5	198.0	178.2	...	49.5	9.0	3.8	1.4
732.....	21.0	4.6	4.5	2.6	3.2	2.0	1.1	3.0	2.8	3.0	44.2	64.0	105.6	251.0	184.8	75.0	63.3	10.4	6.2	2.6
Average.....	9.2	9.3	15.6	5.6	5.3	2.4	4.4	2.2	4.2	5.2	17.5	41.3	62.8	191.7	165.3	52.1	48.1	11.1	4.6	3.7
Av. for unfertilized plats	8.9	3.5	3.9	1.5	3.4	2.4	2.5	2.3	4.0	5.4	14.6	38.1	67.5	193.6	180.7	49.5	50.7	16.1	4.1	3.4

the remainder of May and during June, with a slight increase at the time of harvest, which was continued in the middle of August when the aftermath was growing.

The timothy sod was plowed under in the autumn of 1907, but nitrification had not proceeded very rapidly up to the time of the first analysis on May 19. The most noticeable increase was between July 6 and July 28. At the latter date there was a very large accumulation of nitrates in the soil, probably the maximum of the season. This period of active nitrification was also the time during which the corn was making its most active growth. The weather was warm and very favorable for the growth of corn, which was an unusually good crop this year. It is a striking fact that in spite of the pronounced growth of the corn at this time the nitrates increased at a rate which gave no appearance of their being used by the crop.

Between July 28 and Aug. 10 there was a perceptible decline in the nitrate content, and between Aug. 10 and Sept. 17 this decline was very marked. It is strange that the diminution in nitrates should take place after the period of growth during which the corn plant has been shown to absorb fully one-half of the nitrogen it utilizes.

The analyses of April 22, 1909 which were made before the oats were planted show a much higher nitrate content in the soil in the spring following corn than following timothy, although the analyses were made nearly a month earlier in 1909 than in 1908. Between April 22 and June 24 there was quite a loss of nitrates, as is to be expected from the fact that the nitrogen absorption of the crop is greatest at that time. The lowest figures for nitrates were, however, on July 12 and Aug. 7, although the crop could not have been making very heavy drafts at that time, especially at the latter date, and in the face of the fact that nitrification was at its maximum at those dates under the corn crop.

Indeed it seems that nitrification is not, in the main, determined by the season of the year, but is closely related to the development of the crop. It might be concluded from these data that nitrification is most pronounced during the active growth of the crop upon the soil, and decreases with the less vigorous growth of the crop.

NITRATES ON THE PLANTED AND BARE PORTIONS OF THE PLATS.

As before stated a portion of each plat was not planted in 1908 and 1909, but was given, as closely as possible, the same treatment as the planted portion of the plat. When the planted part of the plat was in corn the bare space was given the same cultivation, and when oats were growing on the planted portion of the plat the bare section was kept free from weeds by scraping the surface with a hoe. In 1908 bare spaces were maintained on the north and south ends of each plat for a distance of 25 feet from each end. When the north end bare space was sampled the north half of the planted area was sampled on the same date, and the same was done with the south part of the plat. The north and south halves were sampled alternately. In 1909 all samples were taken from the south halves of the plats, the bare and planted portions corresponding exactly with those of the previous year. These are referred to as the "north ends," "south ends," "north middles" and "south middles."

A comparison of the nitrate content of the bare and planted parts of the same plat serves to indicate what the effect of the crop has been on the nitrate content of the soil. Table III contains these figures for the years 1908 and 1909.

A striking feature of the nitrate content of the soil during certain stages in the growth of corn is the close agreement between the nitrates in the planted and bare portions of the plats. This is particularly noticeable in the analysis of July 27 previous to which the corn crop must have absorbed about one-half of its nitrogen, judging by what is known of the life-history of the plant. The previous heavy draft on soil nitrates is indicated by the analyses of June 22 and July 6, both of which show a lower nitrate content in the planted sections of the plats. The analyses of July 27 indicate either that the production of nitrates is proceeding much more rapidly in the cropped than in the uncropped soil, or else that the corn crop is absorbing part of its nitrogen in some form other than as nitrates.

The analyses of Aug. 10 show a decline of the nitrates on the planted areas, while the nitrates still continue to increase on the bare spaces. From the stand-point of nitrogen utilization by the crop the decline in nitrates at this late date is difficult to account for.

TABLE III.

NITRATES (NO_3, P. P. M., DRY SOIL) IN PLANTED AND UNPLANTED SECTIONS OF PLATS 711–732, FOR TWO YEARS.

Plat. No.	Corn, 1908										Oats, 1909							
	May 19		June 22		July 6		July 27		Aug. 10		Apr. 22		June 24		July 12		Aug. 7	
	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted	Bare	Planted
711 ch	17.0	25.1	33.0	40.3	64.4	62.0	158.0	182.0	179.2	162.5	63.6	93.8	59.0	37.8	36.2	7.6	63.1	9.8
712	9.5	10.3	50.4	31.5	74.4	52.9	194.0	172.0	176.4	162.5	85.6	61.2	51.6	14.2	56.0	6.9	76.0	3.2
713	35.3	14.5	38.4	40.3	63.4	58.8	198.0	172.0	119.7	201.5	74.8	44.2	77.5	24.7	39.4	8.6	60.8	10.5
714 ch	15.2	22.4	53.7	52.0	63.0	89.6	221.0	268.0	188.5	237.6	86.2	60.2	34.8	18.1	127.0	6.7	56.0	8.0
715	29.0	25.8	44.2	57.2	49.8	60.5	221.0	211.0	163.8	158.4	86.2	56.0	93.1	10.0	129.0	7.9	82.8	10.8
716	30.3	32.6	45.5	69.1	41.6	47.3	255.0	261.0	204.6	156.0	113.8	31.7	48.6	5.0	70.0	5.6	75.6	7.8
717 ch	21.1	20.1	64.0	43.5	46.5	39.0	202.0	211.0	231.0	234.0	112.2	45.5	74.3	16.0	24.0	2.8	86.0	2.4
718	14.0	11.7	47.8	36.5	44.6	39.7	147.0	224.0	156.0	140.8	81.9	56.7	41.1	2.6	48.0	2.5	79.0	2.0
719	18.8	21.4	39.7	30.2	52.7	30.5	176.0	178.0	195.0	160.0	99.4	66.0	58.3	19.2	37.8	2.5	93.7	2.8
720 ch	19.5	16.7	42.8	31.5	70.5	102.4	156.0	211.0	184.8	136.5	81.2	50.1	51.6	12.8	34.6	2.5	77.1	3.3
721	26.8	20.1	53.7	38.4	97.6	66.5	194.0	130.0	198.0	151.8	77.0	36.4	14.3	2.6	12.2	3.8	119.0	4.2
722	24.7	12.0	31.5	32.2	70.5	46.6	194.0	97.5	158.4	138.6	62.7	26.4	70.4	3.9	36.0	2.5	127.0	2.6
723 ch	19.7	11.4	38.4	47.1	48.0	44.7	147.0	141.0	201.6	198.0	89.1	40.2	65.0	3.9	64.7	4.5	85.4	0.8
724	19.7	11.6	47.3	36.5	54.8	50.4	201.0	208.0	184.8	117.0	81.6	30.3	97.0	3.9	41.5	4.5	85.8	1.6
725	19.0	21.4	46.7	50.4	54.5	56.3	201.0	194.0	136.5	105.6	80.4	29.7	60.9	3.3	32.3	4.9	100.0	1.2
726 ch	17.0	10.7	47.3	38.4	39.6	51.2	194.0	238.0	136.0	147.4	50.2	26.8	48.5	4.6	61.2	2.5	65.7	1.1
727	17.0	15.2	40.3	49.2	34.3	75.4	174.0	194.0	178.2	171.6	71.4	41.5	24.9	2.9	59.7	3.1	64.8	1.4
728	22.1	14.7	56.3	42.2	104.1	80.6	168.0	178.0	153.6	165.0	85.0	59.4	32.5	3.9	68.5	6.0	135.0	2.2
729 ch	17.4	4.0	35.3	24.8	83.7	100.8	172.0	158.0	188.5	178.2	83.8	45.5	66.5	21.1	59.6	3.5	31.9	1.1
730 ch	7.2	6.7	42.8	27.3	103.7	50.4	195.0	150.0	221.0	151.8	55.9	44.2	50.4	14.7	46.0	3.4	51.5	1.0
731	36.1	14.3	81.9	26.4	46.9	70.5	238.0	198.0	227.5	178.2	105.6	49.5	47.7	9.0	65.5	3.8	67.0	1.4
732	45.5	44.2	79.3	64.0	103.7	105.6	304.0	251.0	147.2	184.8	122.1	63.3	57.6	10.4	78.9	6.2	114.0	2.6
Average	21.9	17.5	48.1	41.3	64.1	62.8	186.8	191.2	178.6	165.3	84.0	48.1	55.7	11.1	55.8	4.6	81.6	3.7
Aver. of unfertilized plats	16.7	14.6	44.6	38.1	64.9	67.5	180.6	193.6	191.3	180.7	77.7	50.7	56.2	16.1	56.6	4.1	64.6	3.4

The analyses of April 22, 1909, made before the oats were planted shows a continuation of the more rapid decline on the corn land than on the uncropped spaces. The next analysis, June 24, shows an expected decline in the nitrate content of the cropped portions of the plats, as does also that of July 12. By the latter date the nitrogen utilized by the oat crop has, in large part, been absorbed. The last analysis, Aug. 7, shows, however, a still greater decrease in the nitrate content, when we might expect a partial recovery, and when the nitrate content of the uncropped soil has made a very great increase.

Comparing the two crops the following facts are quite significant.

1. When nitrification is at its maximum in the corn land the cropped soil contains more nitrates than the uncropped.

2. In oat land the nitrates are never so high in the cropped as in the uncropped soil.

3. While the maximum nitrate content in the uncropped soil occurred at about the same dates in both years, that in the cropped soil varied with the crops.

4. Under both crops the nitrate content was higher during the period when the crop was making its greatest draft on the soil nitrogen than in the later stages of growth, and this in spite of the fact that the nitrates in the uncropped soil were increasing while those in the cropped soil were disappearing.

These phenomena are explainable on the assumption that nitrification is stimulated by some processes connected with the active growth and absorbing functions of the plant roots, and is inhibited by the conditions accompanying the decreasing activities of the roots.

The large differences in the nitrates under these crops as well as under the corn, potatoes, alfalfa and oats grown by King and Whitson and by Stewart and Greaves may, aside from the influence of cultivation, be sought in the inherent differences between plants of different species in their stimulating or inhibiting effect on nitrification. Another factor which also may be operative in determining the quantity of nitrates is the habits of the plant in respect to the form in which it absorbs nitrogen. It is possible that a plant may induce an active nitrification in the soil and yet absorb its nitrogen largely in the form of

ammonia or even to a certain extent in the form of organic nitrogen, as experiments we are now conducting with corn indicate.

The response of different plants to nitrogen in different forms indicates a difference in their abilities to utilize this material when in certain compounds. Grass, for instance, makes a quick and effective response to sodium nitrate and the nitrate content of the soil, unless heavily dressed with nitrate fertilizer, is maintained at a very low point. Oats are less responsive to the nitrate fertilizer and do not reduce the nitrate content of the soil so low. Corn is but little affected by a nitrate fertilizer, while it is greatly benefitted by fresh applications of farm manure. The nitrates meanwhile are present, apparently greatly in excess of the needs of the plant.

THE RELATION OF NITRATES TO SOIL MOISTURE.

Moisture determinations were made in all soil samples in which nitrates were determined, besides which daily determinations of moisture were made in certain of the unfertilized plats during the summers of 1907 and 1908. It was thought that a record of the moisture content for a period preceding the nitrate determinations would show the relation between soil moisture and nitrate formation better than would a statement of the moisture content on the day on which nitrates were determined. The nitrate content and the average moisture content of the soil for the time intervening between the dates on which nitrates were determined are given in Table IV.

Plat 711 ran perceptibly lower in moisture and higher in nitrates in 1907 than did plat 720. In 1908 there was little difference in moisture and no consistent difference in nitrates. In the latter part of July and first part of August there was a decrease in moisture content in both plats for both years, but in 1907 this was accompanied by an increase in nitrates while in 1908 a decrease occurred. The drying out of the soil and consequent aeration apparently does not appear to produce the same result in both cases, from which it may be taken for granted that factors other than this are more important in nitrate formation.

TABLE IV.

AVERAGES OF DAILY DETERMINATIONS OF SOIL MOISTURE FOR THE PERIODS INTERVENING BETWEEN NITRATE DETERMINATIONS ON CROPPED SOIL.

TIMOTHY, 1907

Plat No.	June 4–6		June 7–13		June 14–20		June 21–July 24		July 25–Aug. 14	
	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.
711	22.8	3.5	23.4	4.6	23.8	3.9	21.7	5.3	17.9	7.2
720	26.3	1.8	26.3	1.8	27.0	1.2	25.1	2.9	21.2	6.0

CORN, 1908

Plat No.	June 2–22		June 23–July 6		July 7–28		July 29–Aug. 10	
	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.	Moisture, per cent.	Nitrates, p.p.m.
711	22.7	40.3	21.1	62.0	24.0	182.0	22.1	162.5
720	22.6	31.5	21.5		25.3	211.0	22.8	136.5

CHANGES IN SOIL MOISTURE.

While the gradual changes in soil moisture content that have been examined do not appear to have been an important factor in promoting nitrification, at least not sufficient to prevail over other influencing conditions, the question arises whether the more

TABLE V.

DAILY MOISTURE CONTENT OF CERTAIN TIMOTHY PLATS IN 1907.

Moisture in soil, per cent. in water-free soil					Moisture in soil, per cent. in water-free soil				
Date 1907.	Plat 711	Plat 720	Plat 728	Plat 729	Date 1907	Plat 711	Plat 720	Plat 728	Plat 729
June 6	23.3	27.3	25.0	27.5	July 14	....	....	....	....
June 7	30.7	32.6	29.9	34.5	July 15	23.3	26.1	23.7	26.6
June 8	25.0	27.5	24.5	28.0	July 16	20.9	23.4	23.3	24.0
June 9	....	....	....	....	July 17	20.0	24.2	23.7	25.1
June 10	....	....	....	....	July 18	21.9	25.1	23.7	26.4
June 11	21.2	23.4	20.7	23.4	July 19	18.9	22.1	19.7	22.1
June 12	20.9	23.7	....	23.4	July 20	18.7	22.6	20.3	22.1
June 13	19.3	24.5	20.6	23.3	July 22	19.0	20.9	20.4	24.2
June 14	19.0	23.0	18.9	21.7	July 23	15.6	20.9	19.0	22.5
June 15	18.9	23.4	17.6	22.8	July 24	16.0	20.1	18.7	21.2
June 16	....	....	....	....	July 25	....	....	....	....
June 17	23.0	24.6	20.6	25.4	July 26	16.8	20.0	19.6	21.7
June 18	14.9	18.6	16.6	18.9	July 27	16.6	19.3	16.0	20.7
June 19	30.3	32.6	31.0	32.4	July 28	....	....	....	....
June 20	37.2	40.0	37.1	41.8	July 29	15.6	19.7	17.5	21.3
June 21	35.1	38.8	36.8	40.2	July 30	14.9	18.7	16.8	20.0
June 22	21.0	24.0	22.2	25.6	July 31	14.5	21.2	17.6	19.6
June 23	....	....	....	....	Aug. 1	16.1	19.4	17.5	21.2
June 24	18.7	22.1	19.3	22.8	Aug. 2	20.1	25.3	23.4	25.6
June 25	18.6	22.4	17.3	23.6	Aug. 3	21.0	23.3	23.8	24.6
June 26	22.4	24.6	21.9	27.3	Aug. 4	....	....	....	....
June 27	22.8	20.3	18.6	23.8	Aug. 5	21.3	22.6	23.0	23.6
June 28	20.6	Lost	19.6	25.3	Aug. 6	19.7	24.2	24.0	25.4
June 29	19.4	21.7	17.7	22.2	Aug. 7	19.4	23.0	22.5	23.1
June 30	....	....	....	....	Aug. 8	18.6	21.9	22.6	23.6
July 1	26.4	29.7	28.2	31.0	Aug. 9	18.7	22.5	22.2	23.1
July 2	27.5	31.0	29.3	29.5	Aug. 10	18.9	21.0	20.9	22.5
July 3	25.6	28.2	27.5	27.5	Aug. 11	....	....	....	....
July 4	....	....	....	....	Aug. 12	17.5	19.9	20.4	19.1
July 5	24.2	27.0	25.3	27.0	Aug. 13	18.3	19.3	21.0	21.2
July 6	22.5	25.4	24.0	25.7	Aug. 14	16.6	20.1	18.7	20.1
July 7	....	....	....	....	Aug. 15	15.7	17.9	17.6	19.9
July 8	20.0	23.7	23.3	23.8	Aug. 16	16.2	17.3	17.7	18.9
July 9	19.6	23.6	21.6	23.7	Aug. 17	15.2	17.2	16.4	17.5
July 10	18.7	20.7	19.3	21.5	Aug. 18	....	....	....	....
July 11	19.4	20.6	20.9	19.7	Aug. 19	14.8	16.4	13.3	15.0
July 12	25.9	31.2	29.9	30.2	Aug. 20	12.4	16.5	15.2	15.3
July 13	26.4	29.2	28.2	29.2					

frequent, although less marked changes in moisture content, due to the effect of transpiration from the plant in drying out the soil between rains would not cause greater nitrification on the planted than on the unplanted sections of the plats.

Analyses made in the course of the experiments here described give the daily moisture content of the planted sections

on certain plats throughout the growing season. There were also moisture determinations made in each of the soil samples, in which nitrates were determined, and these show to what extent the cropped soils dried out as compared with the uncropped soils. These data are given in Tables IV to VII respectively.

It will be seen from these tables that while there is considerable range in the maximum and minimum moisture content of these plats that the changes are not rapid, at least the

TABLE VI.

DAILY MOISTURE CONTENT OF CERTAIN CORN PLATS IN 1908.

Date 1908	Plat 711 S M	Plat 720 S M	Plat 728 S M	Plat 729 S M	Date	Plat 711 S M	Plat 720 S M	Plat 728 S M	Plat 729 S M
June 2	27.3	26.8	26.5	26.5	July 11	24.0	21.7	21.7	21.3
June 3	25.1	25.7	26.1	24.2	July 13	26.8	26.7	27.5	26.1
June 4	26.1	24.0	25.0	24.2	July 15	23.1	25.1	24.2	25.0
June 5	24.6	24.8	24.5	23.8	July 16	21.0	23.6	23.7	23.3
June 6	23.8	24.5	23.6	23.3	July 18	22.5	24.2	24.2	22.8
June 8	21.9	21.2	22.2	20.3	July 20	21.7	22.8	23.8	22.2
June 9	20.3	21.6	22.8	21.3	July 21	21.7	22.6	23.7	22.6
June 10	20.9	21.7	22.6	21.5	July 22	26.4	29.7	28.7	28.0
June 11	22.1	21.5	21.7	20.6	July 23	26.4	28.8	27.8	27.2
June 12	20.3	20.9	21.2	21.2	July 24	24.2	26.8	26.5	25.6
June 13	23.6	21.5	23.8	20.7	July 25	28.8	30.3	31.9	27.8
June 16	22.5	23.4	23.4	22.8	July 27	26.8	28.5	26.7	26.7
June 17	21.6	22.4	22.8	22.4	July 28	24.8	27.0	27.2	27.5
June 19	20.	20.7	22.8	22.1	July 29	23.6	25.1	25.1	23.0
June 20	22.1	21.0	21.3	20.7	July 30	23.4	24.2	24.2	22.8
June 22	21.5	21.2	22.4	20.9	July 31	22.4	22.5	24.3	22.1
June 23	21.0	22.6	22.2	21.5	Aug. 3	19.3	19.9	21.0	19.6
June 24	21.5	21.7	22.2	21.3	Aug. 4	18.7	20.3	21.3	19.1
June 25	20.6	21.5	23.3	21.5	Aug. 5	23.0	21.9	23.4	23.0
June 26	20.6	21.3	22.6	21.5	Aug. 6	22.1	23.1	24.6	23.1
June 27	21.7	21.2	23.1	21.7	Aug. 8	24.5	25.6	25.7	25.9
June 29	20.1	20.9	23.3	20.6	Aug. 11	21.0	20.7	23.1	23.0
June 30	21.6	21.7	22.5	21.3	Aug. 12	20.9	21.0	23.0	21.3
July 1	21.5	21.2	22.6	20.7	Aug. 13	18.2	19.0	21.6	20.9
July 2	20.7	21.5	....	19.6	Aug. 14	21.3	22.2	23.1	22.2
July 3	21.3	21.2	22.4	20.0	Aug. 18	22.5	22.4	24.5	24.2
July 7	20.9	21.0	21.5	20.9	Aug. 19	21.2	22.4	24.6	21.7
July 8	23.1	23.4	24.6	23.1	Aug. 20	21.6	21.7	23.0	21.7
July 9	22.5	22.6	23.8	22.1	Aug. 21	20.0	21.0	21.9	21.7

drying-out process is slow and that is the one that causes aeration. Furthermore, it is quite apparent that on the corn soil in which nitrification is most active, the changes in the moisture content of the cropped soil do not differ greatly from those on the uncropped soil on the same dates. It is also very evident that the changes in the moisture content go on all through the summer and should therefore induce nitrification during the later growth of the crop as well as in the early stages, while Table II shows that nitrification is greater on the planted soil only during the

earlier stages of growth. While soil moisture content is undoubtedly a factor in nitrification in this soil under otherwise similar conditions and in some soils may be the controlling influence, the effect in these plats was evidently counterbalanced

TABLE VII.

MOISTURE CONTENT FOR PLANTED AND BARE SECTIONS OF CORN PLATS IN 1908 ON DATES DESIGNATED.

Date	Plat 711, unplanted S	Plat 711, planted S M	Plat 720, unplanted S	Plat 720, planted S M	Plat 728, unplanted S	Plat 728, planted S M	Plat 729, unplanted S	Plat 729, planted S M
June 3	27.0	25.1	....	....	....	....	....	....
June 4	....	....	23.3	24.0	....	....	....	....
June 5	....	....	....	....	25.0	24.5	....	....
June 6	....	....	....	....	....	....	22.6	23.3
June 9	21.6	20.3	....	....	....	....	....	....
June 10	....	....	21.0	21.7	....	....	....	....
June 11	....	....	....	....	23.1	21.7	....	....
June 12	....	....	....	....	....	....	21.5	21.2
June 16	23.6	22.5	....	....	....	....	....	....
June 17	....	....	21.9	22.4	....	....	....	....
June 19	....	....	....	....	24.5	22.8	....	....
June 20	....	....	....	....	....	....	21.0	20.7
June 24	22.5	21.5	....	....	....	....	....	....
June 25	....	....	21.5	21.5	....	....	....	....
June 26	....	....	....	....	23.1	22.6	....	....
June 27	....	....	....	....	....	....	22.1	21.7
June 30	21.7	21.6	....	....	....	....	....	....
July 1	....	....	20.6	21.2	....	....	....	....
July 2	....	....	....	....	23.3	....	....	....
July 3	....	....	....	....	....	....	21.3	20.0
July 8	24.6	20.1	....	....	....	....	....	....
July 9	....	....	23.4	22.6	....	....	....	....
July 11	....	....	....	....	23.4	21.7	....	....
July 13	....	....	....	....	....	....	28.2	26.1
July 16	24.5	21.0	....	....	....	....	....	....
July 18	....	....	23.4	24.2	....	....	....	....
July 20	....	....	....	....	25.0	23.8	....	....
July 21	....	....	....	....	....	....	23.0	22.6
July 23	28.0	26.4	....	....	....	....	....	....
July 24	....	....	26.4	26.8	....	....	....	....
July 25	....	....	....	....	31.7	31.9	....	....
July 27	....	....	....	....	....	....	27.2	26.7
July 29	24.5	23.6	....	....	....	....	....	....
July 30	....	....	22.6	24.2	....	....	....	....
July 31	....	....	....	....	24.6	24.3	....	....
Aug. 3	....	....	....	....	....	....	20.0	19.6
Aug. 5	21.0	23.0	....	....	....	....	....	....
Aug. 6	....	....	21.9	23.1	....	....	....	....
Aug. 8	....	....	26.7	25.6	....	....	....	....
Aug. 11	....	....	....	....	23.8	23.1	....	....
Aug. 12	....	....	....	....	....	....	21.7	21.3
Aug. 14	23.4	21.3	....	....	....	....	....	....
Ang. 18	....	....	23.3	22.4	....	....	....	....
Aug. 19	....	....	....	....	24.0	24.6	....	....
Aug. 20	....	....	....	....	....	....	22.1	21.7

by other factors. The more active nitrification in the cropped than in the uncropped soil during early growth and the reversal of this in a later period has no apparent relation to the moisture content of the soil.

(To be continued.)

THE AIR-BRAKE AS RELATED TO PROGRESS IN LOCOMOTION.

BY

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(*Concluded from Vol. CLXX, p.* 494.)

To consider for a moment the quantitative results of the improvements which have been mentioned as evidenced by the comparative stopping distances of trains equipped with the types of brakes referred to. The diagram (Fig. 18), shows concretely

FIG. 18.

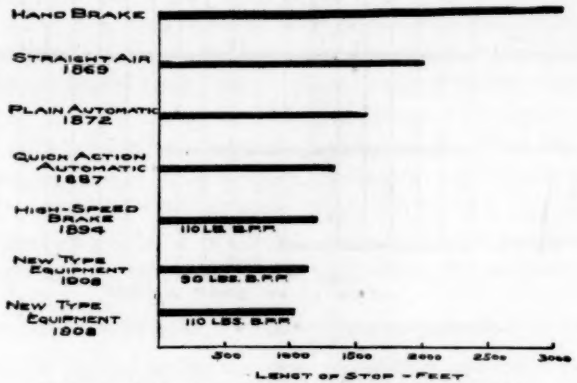
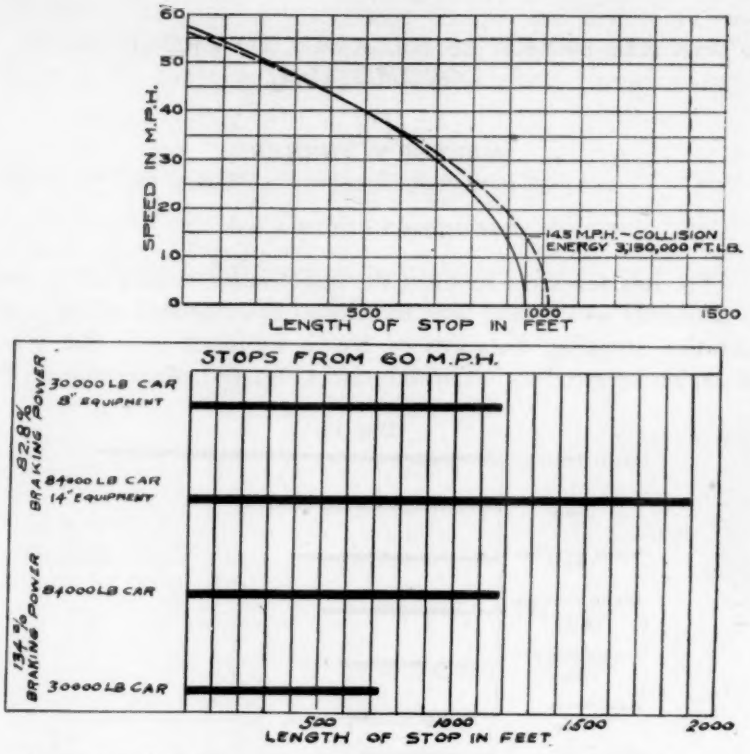


Diagram of development of air-brake efficiency since 1869.

the relative efficiency of the various forms of brakes for passenger trains, the difference in the length of the lines corresponding approximately to the reduction of distance required in which to stop a given train of one locomotive and six cars from a speed of 60 miles per hour since the introduction of the air-brake. If the diagram were inverted so that it is viewed upside down, a fair idea will be obtained of what the relation between the stops would have been through the respective periods of train development had there been no change in the air-brake since first applied.

The tendency of modern rolling stock to lower brake efficiency is further illustrated in Fig. 19. The retardation curves show

FIG. 19.



Comparative retardation curves and braking power chart for trains of 1875 and 1907.

Date	Speed in M.P.H.	Length of stop in feet	Time of stop in sec.	Weight of trains, tons	Work in ft.-tons performed by brakes			B. P., per cent.
					Total	Per sec.	Per brake-shoe per sec.	
1875	56.0	1020	22.0	227	23900	1086.4	14.70	82.8
1907	57.3	954	18.7	559	61300	3278 0	28.75	150.0

Dotted curve shows stop on Midland Railway, 1875, with the Westinghouse Automatic-Brake.

Full-line curve shows stop made on W. J. and S. R. R., 1907, with the Westinghouse "LN" Brake.

Had the braking power as shown in the last column of the table and represented by the full-line curve, been 134 per cent. instead of 150 per cent., the two stops would have been the same.

the stopping distance from about the same initial speed of a train composed of cars weighing 30,000 pounds and braking at 83 per cent. and a train of 84,000 pounds cars braking at 150 per cent. It will be seen that notwithstanding the 60 per cent. greater braking power of the heavier train, the difference in stop is not greatly in its favor. The reason for this is clear when it is considered that the work done during the stop for the light train was 14.5 foot-tons per brake-shoe per second while with the heavy train it was 29 foot-tons per brake-shoe per second, which shows that under modern conditions each brake-shoe is doing about twice the amount of work required formerly in order to make approximately the same stop, which consequently lowered the coefficient of friction and thus tended to equalize the actual retarding forces developed in the two cases.

The diagram below the comparative curves shows, first, the length of stop for light train with the equipment of its day; second, what the stop would have been with the heavier train had there been no change in brake equipment to correspond to the increased weight of train; third, what braking power was actually required to stop the heavy train in the distance the light train was stopped with its brake equipment; and fourth, what the stop of the light train would be if it were possible to apply to it the brake equipment required for the heavy train. This is a significant and all-sufficient example of what is required to meet modern conditions as effectively as they were provided for in the past.

CONTROL VALVE EQUIPMENT.

With the introduction of heavy sleeping cars and passenger equipment cars carrying heavy motive power apparatus such as self-contained motor cars, not only were the factors above mentioned, which tend to lower brake efficiency, aggravated to a marked degree, but limiting conditions were encountered in other directions. The brake force required to control such heavy (135,000 to 170,000 pound) cars with approximately the same effectiveness obtainable with the apparatus used on lighter cars became so great as to exceed the capacity of a single brake-cylinder even with the highest brake-cylinder pressure and greatest multiplication of its power by leverage that could be permitted.

The single brake-cylinder had already reached a maximum of 18 inches in diameter and it was generally agreed that a larger

size brake-cylinder would be impracticable from a manufacturing, operative and maintenance stand-point.

With 100 to 105 pounds brake-cylinder pressure being obtained from 110 pounds brake-pipe pressure carried there was little hope of raising the cylinder pressure higher and no material or permanent improvement in the general condition would result even if the full 110 pounds could be realized in the brake-cylinders.

There was no suggestion of an increase in brake-pipe pressure above the present standard, it being universally recognized that 110 pounds was about as high as could safely and economically be used with the type of apparatus and fixtures in general service.

The multiplication of the brake-cylinder pressure through the leverage of the foundation brake rigging had been carried, in many cases, beyond the recommended 9 to 1 maximum simply because it was the most obvious, simplest, and most convenient means of providing the heaviest cars with a proportionate braking power approaching that used on lighter cars. The evils of this expedient soon became manifest in dragging brake-shoes, "slow release" and trouble in keeping the brake rigging properly adjusted. Most important of all, from a safety stand-point, was the effect of this high leverage ratio in multiplying the losses due to lost motion in the rigging or truck members, brake-shoe movement and so on, the result of which was evidenced in excessive false piston travel and consequent failure to obtain the maximum brake-cylinder pressure contemplated in the design, or still more serious loss in braking power due to the piston travelling so far as to bottom on the cylinder head.

These and other mechanical limitations therefore barred further progress in this direction and two alternatives remained, viz.:

1. To increase the effectiveness of the single brake-cylinder as far as possible by using two brake-shoes per wheel (clasp brake).

2. To use two brake-cylinders per car.

While the first of these alternatives would undoubtedly be of some assistance, there are objections to this design, not the least of which is a reasonable doubt whether the acknowledged theoretical advantages of the clasp brake would prove to be prac-

ticable; and a reasonable certainty that no matter to what extent its theoretical advantages might be realized in practice, the maximum increase in efficiency thus afforded could not be sufficient to meet the demands of conditions already existing, to say nothing of the possibilities of the future.

On the other hand, the two-brake-cylinder proposition did not necessarily involve any new or untried principles, since two complete equipments of the type already in service might be used, one for each end of the car. This would provide ample stopping power for existing conditions and lend itself readily to extension, as still more severe demands might arise. It was therefore recognized that such an arrangement offered the best solution of the problem of the proper air-brake equipment for passenger cars weighing 130,000 pounds or over. Furthermore, it was seen that a single valve mechanism to control the admission of air to and release of air from the two-brake-cylinders would possess such marked advantages over a complete double equipment for each car as to make a satisfactory and practicable design of such a valve greatly to be desired. In reality, the success and scope of the two-cylinder arrangement depended wholly on the characteristics of the valve device adopted for this purpose.

It was but logical that, in the first practical solution of this problem, use was made of the same principles, both of construction and operation, as had been embodied in a valve device already in use for some years and giving the best of satisfaction under conditions quite similar to those of the two-cylinder passenger-car equipment. While this valve (the distributing valve of the "ET" locomotive brake equipment) was particularly designed to operate in connection with two or more brake-cylinders on locomotives, its distinctive operative features were equally advantageous for passenger car service. Consequently, when the introduction of 85-ton multiple unit electric motor cars on the N. Y., N. H. & H. R. R. electric zone called for a correspondingly effective form of brake apparatus, of necessity using two-brake-cylinders, the valve mechanism adopted was a modification of the distributing valve type, the changes being only such as were required to adapt this device to passenger train service. From the start, its performance under the severe demands of suburban electric service was so satisfactory as to thoroughly establish the advantages of this type of equipment for the high braking

efforts and large brake-cylinders required by the heavier classes of cars. It is hardly necessary, however, to go further into detail regarding its construction or operation, first, because the design of its operating mechanism resembles so closely that of the distributing valve, and, second, since it served to mark one stage only in the development of a distinct type of brake apparatus for such service.

As already stated, with the advent of passenger carrying cars weighing from 135,000 to 150,000 pounds in steam road service and still heavier motor cars, carrying extraordinary dead weight loads, the limit of an efficient single-cylinder equipment was approached and in some cases exceeded. But this was only one phase of the situation. The demand of high speed heavy train service had steadily advanced to a point where, for adequate control, something more was required of a brake than merely maximum retarding power in emergency. The ordinary service functions and automatic safety and protective features became hardly secondary in importance. Briefly stated, the requirements recognized as essential in a satisfactory brake for this modern service are as follows:

1. Automatic in action.
2. Efficiency not materially affected by unequal piston travel or brake-cylinder leakage.
3. Prompt serial service action.
4. Graduated release.
5. Quick recharge and consequent ready response of brakes to any brake-pipe reduction made at any time.
6. Predetermined and fixed flexibility for service operation.
7. Full emergency pressure obtainable at any time after a service application.
8. Full emergency pressure applied automatically after any predetermined brake-pipe reduction has been made after equalization.
9. Emergency braking power approximately 100 per cent. greater than the maximum obtainable in service applications.
10. Maximum brake-cylinder pressure obtained in the least possible time.
11. Maximum brake-cylinder pressure maintained throughout the stop.

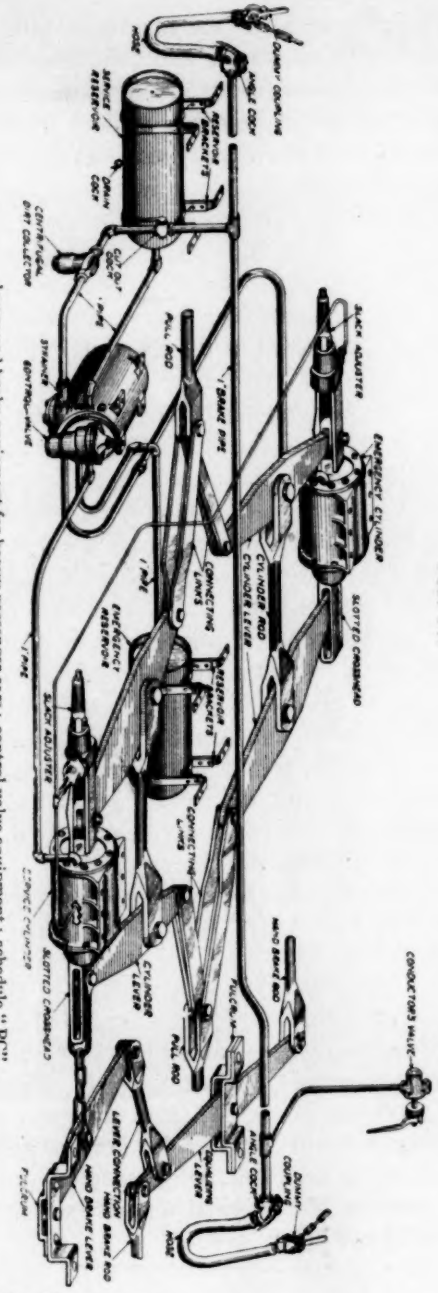


FIG. 20.

Improved brake equipment for heavy passenger cars; control valve equipment; schedule "PC".

12. Brake rigging designed for maximum efficiency.

13. Adaptability to all classes and conditions of service.

That certain of these requirements demanded radical changes in the valve device used on the car is evident from a comparison with the functions of the previous types already referred to, since but one of these required functions was contained in the older equipment. These considerations led to the latest development in the art of controlling heavy, high-speed passenger trains, employing what is known as a control valve in the place of a triple valve, the functions of which have already been mentioned in brief. The complete equipment is known as the schedule "PC" and is illustrated in Fig. 20.

The relative stopping power of the most efficient of the old order of brake apparatus—the High-Speed Brake—and of the control valve apparatus, is contrasted in the curves of Fig. 21. Both the comparative lengths of stop and the relative rates of rise and amount of maximum braking power are shown by the curves. It will be noted that the 575 foot shorter stop made with the "PC" equipment resulted not only from the higher braking power utilized but also from the quicker rate at which this braking power was built up to its maximum value. As a result you will note that the speed of the high-speed equipment train when passing the point (1100 foot stake) at which the "PC" equipment train stopped, was still as high as 38 miles per hour which means that 40 per cent. of its initial kinetic energy (at 60 miles per hour) still remained to be dissipated (harmlessly in this case, fortunately) before the train could be stopped.

Moreover, not only was this speed 38 miles per hour in the case of the high-speed equipment train, but it passed the 1100-foot stake 6 seconds before the "PC" equipment train reached that point. That is to say, the train with the "PC" equipment came to a stop at the 1100-foot stake 6 seconds after the train equipped with the high-speed equipment passed this point at a speed of 38 miles per hour. At the time when the "PC" equipment train stopped at the 1100-foot stake, the train equipped with the high-speed brake equipment was 275 feet further on, and still running at a speed of 28 miles per hour, which corresponds to a kinetic energy 22 per cent. of the original amount when the train was running at 60 miles per hour.

SUMMARY OF DEVELOPMENT IN PASSENGER BRAKES.

From what has gone before, it will be seen that the existence and development of the passenger brake devices which have been described have come about, not spontaneously, of themselves, or

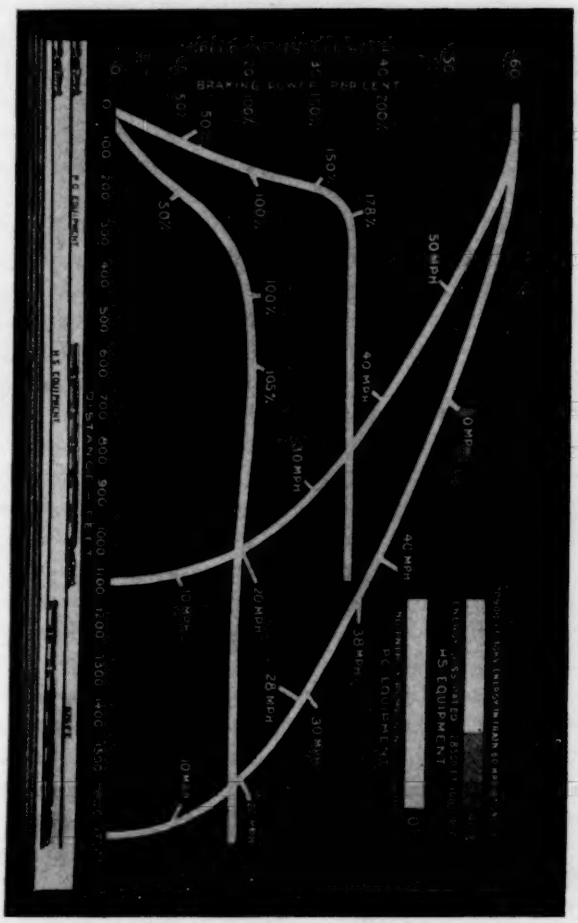


FIG. 21.

Comparative train stops, control valve and high-speed brake equipments.

solely for themselves, but in response to a definite need or for the purpose of accomplishing certain necessary and desired results, the end in view always being the safeguarding of life and property and increasing the facility, economy, and dispatch with which larger volumes of traffic can be handled.

Briefly, the conditions to be overcome and the objects to be attained may be summarized as follows:

CONDITIONS.—Increased weights of trains, greatly decreasing the relative efficiency of the brake and increasing the energy to be overcome in bringing the train to a standstill. Of two trains on the same number of wheels having the same nominal percentage of braking power, one being twice the weight of the other, the heavier train will run at least one-third further than the other.

Higher running speeds, increasing the energy to be overcome in making the stop in proportion to the square of the speed and adding directly to the length of stop according to the time required to obtain effective braking power on the train as a whole.

Greater frequency of trains, which increases the necessity for stopping quickly in a rapidly increasing ratio. Not only is it of more importance than ever that the trains be readily controlled within the distances between signals, but, with double- or four-track roads, there is the added greater possibility of the track on which the train is running being blocked by a break-in-two or other accident on the opposite track.

Increasing insistence upon the comfort and convenience of passengers and at the same time for greater economy in the handling of traffic, the latter being, in the nature of things, antagonistic to the former, without some special provision is made, looking to ultimate rather than circumstantial economy.

OBJECT OF IMPROVEMENTS.—*In Service Applications.*—(1) Much more flexible control of the train, greatly reducing possibility for shocks. (2) More uniform braking power, reducing surging in trains and flat wheels. (3) Uniform and maintained cylinder pressure notwithstanding variations in piston travel or leaky brake-cylinders. (4) Constantly recharged auxiliary reservoirs, which increase the safety to the highest degree. (5) Better protection against excessive braking power in service applications. (6) Shorter, smoother and more accurate stops.

In Emergency Applications.—(1) The human factor in the equation is reduced to a low point. (2) The increased percentage of braking power and prompt rise of brake-cylinder pressure compensates in a large degree for the decrease of the retarding force due to the increased work the brake-shoe now has to perform as compared with the old style brake. (3) Trains can be stopped in somewhere near the same distance as when

the cars were lighter. (4) *Emergency Pressure is Available Even After a Service Application Has Been Made to an Extent Never Before Attained.*

EMPTY AND LOAD BRAKES.

Under modern freight-traffic conditions, as already stated, uniformity of retardation on all cars in a train is second in importance only to safety. This, with mixed loads and empties hauled in the same train, is inherently unobtainable with the type of brake considered thus far. It can only be accomplished by providing means whereby a relative braking force more nearly comparable to that of the empty car can be utilized on the partially or fully loaded car.

The difference in braking power with the standard brake on loaded and empty cars would no doubt astonish anyone unfamiliar with the facts, but can be appreciated from the statement that the same brake-cylinder pressure which gives 60 per cent. braking power on an empty car will give only from 17 per cent. to 20 per cent. when this same car is loaded to its full capacity.

Four possible solutions are evident:

1. *Increased Brake-cylinder Pressure for a Given Reduction and on Equalization.*—In order to leave the braking power on the empties the same as at present but increase that on the loaded car to the desired amount, it would not be permissible to increase the brake-pipe pressure above the 70 pounds at present generally used. Even if an increase above 70 pounds *for this purpose* were permissible, it would not give any higher braking power for ordinary service reductions, but only afford a higher equalization pressure. An increase of reservoir volume, on the loaded car is therefore another alternative. The maximum increase in pressure then available could not be greater than 70 pounds which, while only increasing the braking power on the loaded car by 40 per cent. (that is, from, say, 20 per cent. to 28 per cent. braking power) at the most, would destroy many fundamental and necessary features of the brake. This is only about one-fifth or one-sixth of the increase required for a proper control of a car loaded to from two to four times its light weight. This method is therefore impracticable.

2. *Increase the Total Leverage Ratio Temporarily on the Loaded Car.*—In the first place, the total leverage ratio for the

heavier modern freight cars and standard equipment is already so high that any such increase as required by the loaded car would be prohibitive. Aside from this, however, it has been demonstrated by many repeated but futile attempts that none of the various schemes thus far proposed for mechanically changing the leverage to correspond with the increase in car lading (whether automatically with an increase of car weight or manually) can be made practicable for actual road service. Once established for the light car, the same leverage ratio must be utilized for the loaded car.

3. *A combination of increased leverage ratio and auxiliary reservoir volume* might be suggested as a possibility but it would evidently combine the objectionable features of the first and second alternatives just mentioned in such a manner as to aggravate the undesirable effects of each. This method, therefore, fails to afford the relief sought.

A fourth possibility remains, viz.:

4. *A Second Brake-cylinder to be Added to the Ordinary Brake-cylinder to Control the Load.*—A number of equipments of this type, of varying form, are being successfully operated on a number of railroads, particularly in mountain grade service, where the additional braking power thus provided is of advantage in increasing the amount of tonnage handled in a given time down the grade. It will be of interest to state, in outline only, the characteristic features of forms which have proven successful.

1. Two brake-cylinders per car are used, one for the empty car and both used together when the car is loaded to say two-thirds or more of its rated capacity.

2. Standard leverage arrangement for the "empty" brake-cylinder.

3. Suitable connections, take-up mechanism, levers, etc., to form the connection and required multiplication of power from the additional "load" cylinder to the "empty" cylinder lever system.

4. Valve mechanism, in addition to that required by the "empty" brake, for controlling the supply of air to and from the added or "load" brake-cylinder.

5. Semi-automatic change-over valve-mechanism for cutting the "load" brake in or out either manually or under certain circumstances, automatically.

6. Additional reservoir capacity to furnish the air supply for the "load" brake.

The important problems entering into the operation of brakes on freight trains under present-day intensive traffic duty, for which the "empty and load" type of apparatus offers an ideal solution may be briefly stated as follows:

1. The necessity for more braking power on loaded cars than afforded by the ordinary form of brake, in order to increase the tonnage which can be handled down long or heavy grades with safety. Locomotives of such power are now built, that it is possible, in some localities, to haul heavier trains to the top of the grades than can be safely controlled down the other side with the standard brake.

2. Trains of mixed loads and empties, especially long (50 to 100 cars) trains, where it is physically impossible or economically impracticable to arrange the empty and loaded cars in the train to the best advantage, thus adding greatly to the danger of the train parting or damage to the lading and equipment due to inequality of braking power in different parts of the train, when the brake is applied at some critical speed or locality.

3. Locomotives of great weight, but relatively low braking power, tending to increase the internal stresses in the train due to unequal retardation on diffrent cars in the train.

4. The advent of large capacity cars, aggravating the differences in retardation due to lading, so that the percentage of braking power on such cars, when loaded, is reduced to a greater extent than on cars of lower capacity, for which the proportion of loaded to light weight is less.

5. The requirement of operating both short and long freight trains with practically all air-brakes cut in. This, on a long train, with loads ahead and empties on the rear end, presents an operating problem difficult of solution with the old standard brake.

PRINCIPLES OF TRAIN BRAKING AND BRAKE DESIGN.

Throughout the foregoing description of the development of the various types of brake apparatus, occasion has been taken to explain at the same time the operating conditions and service requirements responsible for their being. While this has necessarily involved some reference to some of the fundamental principles underlying the proper application and operation of brakes

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Throughout the foregoing description of the development of the various types of brake apparatus, occasion has been taken to explain at the same time the operating conditions and service requirements responsible for their being. While this has necessarily involved some reference to some of the fundamental principles underlying the proper application and operation of brakes

as related to convenience, economy and safety in train control, there are certain limiting conditions and fixed laws which should be treated more specifically and in detail. This is not so much because the present state of the air-brake art exemplifies the application of these laws and principles to the complex demands of modern freight and passenger service, but rather because it is only by a careful study and sound working knowledge and appreciation of the significance of these laws that anyone is able to judge positively and accurately, on the one hand, the adaptability of, or necessity for, any new air-brake device, and on the other, what are the requirements to which any new device or method must conform in order to adequately and efficiently satisfy the requirements of new service conditions.

STARTING AND STOPPING.

The problems of deceleration, retardation and the flexible control of trains must receive more and more attention from a scientific and technical stand-point, in order that to-day theory and practice may be combined to produce the best results in the shortest time. This is necessary if the brake is to efficiently and satisfactorily meet the wonderfully changed conditions which have developed since the invention of the quick action, automatic brake. The high speeds and great weights of the present day requiring that advantage be taken of every opportunity offered to increase and flexibly control braking power.

Starting and stopping of trains are complementary factors in the problem of making time between stations, therefore it is evident that the best results can only be obtained where both factors are given due consideration. Generally, the starting factor is the only one fully considered, or, at least, the one more fully provided for, and this notwithstanding that better results can be obtained if both are considered and the more efficient brake system installed.

In another sense, the question of stopping is the most important, as the safety of the service and the freedom of delays to a great degree depend upon it. The measure of the value of the brake is two-fold,—(1) the ability to stop in the shortest possible distance when necessary; and, (2) to permit short, smooth and accurate stops being made in regular operation. Therefore both these factors should be considered when design is under way.

FIG. 22.

CLASS E-2-D LOCOMOTIVE.

TOTAL WEIGHT OF TRAIN	559.6 TONS.
ACCELERATION	DISTANCE OF 18500 FEET
TIME OF ACCELERATION	5 MIN. 47 SEC.
DECELERATION	DISTANCE OF 954 FEET.
TIME OF DECELERATION	18.7 SEC.

TOTAL ENERGY STORED IN TRAIN AND OVERCOME BY BRAKE 63250 FOOT TONS

BROKEN LINE REPRESENTS STOP WITHOUT THE USE OF BRAKES.

NOTE:- THE CALCULATED STOP WITHOUT BRAKES WAS OBTAINED BY ASSUMING 9.6 POUNDS PER TON RETARDATION DUE TO WIND RESISTANCE AND JOURNAL FRICTION. TRACK LEVEL.

Acceleration and deceleration curves; Absecon tests.

Unfortunately, the brake is usually looked upon as a safety device only, and it is because of the prevalence of this idea that its installation and maintenance do not receive the consideration merited. Considering the investment, there is no part of the railway equipment that will give greater material returns than the brake when properly installed, operated and maintained. If the brake could to some extent be separated from the idea or impression that it is a safety device only and proof advanced to show that it makes possible the hauling of heavier cars,—in fact, makes the heavy car possible,—that it makes possible, faster and more frequent service,—as much or more than does the locomotive, the block signal and the good roadbed,—and that, if given the consideration it should have, it would increase the possibilities, profits and value of all these things,—its importance would be more fully appreciated and, therefore, at least the same consideration be given to its design and installation that is accorded to other parts of railway equipment. A safety device, the brake is, par excellence; but it has other reasons for its existence.

Very few, perhaps, realize that the brake under a single car is much more powerful than the locomotive that pulls the train, yet this will be apparent to any who examines the records of a dynamometer car alone attached to an engine, the stops being made by brakes on the dynamometer car. Few realize that it takes a locomotive perhaps five minutes, perhaps ten minutes, and a distance of some miles,—six or seven,—to attain a speed of sixty miles per hour. Imagine the condition of affairs which would exist if it took a brake that length of time and distance to stop the train. The comparison is somewhat startling, but it is only because the condition is one of those commonplaces which have been taken for granted so long that they are accepted as inherent rather than being given the degree of consideration which their significance warrants. Fig. 22 is an illustration of the facts stated, taken from the records of a run during a series of tests at Absecon, N. J., 1907, the train being composed of a locomotive and ten cars. What it took the locomotive nearly six minutes and a distance of about three and a half miles to accomplish was overcome by the brakes in less than twenty seconds and within a distance of about one thousand feet. The broken line represents what the stop might have been if no brakes had been used, *i.e.*, the train brought to rest by the resistance of the air, and

journal friction. All of the elements so strongly contrasted in Fig. 22 are familiar in themselves but their reciprocal relationship is often overlooked. The average passenger train of to-day can be stopped from a speed of sixty miles per hour in about twenty seconds' time. To build a steam locomotive that would accelerate a train in the time and distance that the brake stops it, would be impossible, for in order to have the necessary adhesion to the rails, which would permit of developing the required drawbar pull, the steam locomotive would have to weigh approximately twice as much as the train itself, which is, of course, prohibitive. Electric locomotives, however, are no longer to be regarded with uncertainty or as mere experiments and there is every reason to believe that the electric locomotive will be able to accelerate a train to a speed of sixty miles an hour in certainly not more than a minute and a half, and probably not more than one minute's time. That means that the brake is going to be even *more* important in the future than it has been in the past. In proportion as we accelerate, we must perforce be prepared to decelerate. The ability to accelerate, or even to run at high speeds, must be measured by the ability to stop.

As an example, however, of how little this is appreciated such a question as the following is often asked and a categorical answer apparently expected: "In what distance should a train be stopped from a speed of fifty miles per hour?" Perfectly simple, isn't it? Here we have one known factor, from which we are expected, apparently, to derive all the other factors which are of equal importance and must be known before an answer of any value can be given to such a question. A few of these factors are: the light weights and loads of the vehicles composing the train; the percentage of braking power used with engine and cars; whether or not all wheels, including truck and trailer (if any), of the locomotive were braked; what type of brake equipment was used; what pressures were carried; whether the train was accelerating or decelerating; on a curved or straight track; on an ascending or descending grade, or level; the condition of the rail; whether the brakes were applied in service or emergency, or ordinary service and then emergency; the piston travel on each vehicle: the losses to friction of parts, brake-beam release springs, etc.; wind resistance; quality and thickness of brake shoes and method of hanging them, for this affects materially the efficiency of the brake, both as to absorbing power and lengthen-

ing the piston travel which reduces the pressure otherwise obtainable. Furthermore, it should by no means be understood that the precise effect of each of these could be accurately calculated, even though full information were at hand, and a little thought will make it evident that each of the factors mentioned above may have a considerable influence on the length of the stop.

These things are merely mentioned to emphasize the great importance of the air-brake and the necessity for considering carefully what principles govern its action. It does not make very much noise. It does not occupy so prominent a place in the papers as electricity, for instance; yet it has been much more of a factor in railroad development up to the present time than electricity.

I may be pardoned for asking you to form a comparison between the propelling and stopping mechanism of our steam railroads. The locomotive is much in evidence, being large and of powerful appearance and placed in the most conspicuous place in the train. The brake is, outwardly, a comparatively insignificant piece of apparatus, installed on the different vehicles of the train; placed underneath the cars where it is hard to find, and seldom observed by the traveller. The very fact that it is so distributed over the train is one reason for its power and efficiency. When we realize the forces handled by the two devices, and the great difference in point of time in which their work is accomplished, our respect for the brake will be stimulated, since it *must* be capable of dissipating the energy, stored by the locomotive in the train, in but a fraction of the time required by the locomotive to do this, if the safety of transportation is to be preserved.

FUNDAMENTAL PRINCIPLES IN BRAKE DESIGN.

In the establishment of a logical basis of brake design, applicable to the conditions under which brakes in general must operate and involving a determination of the essential elements of an elementary brake system for any given car, the starting point must be the light weight of the car. Fortunately this can usually be determined in advance to any desired degree of accuracy. For convenience, suppose the car to be fully equipped with a complete brake equipment and by an analysis of the factors involved in stopping the car, determine how these factors may best be provided for in the design.

Assuming that the wheels do not skid, the actual *braking force* acting on a car when the brakes are applied is the force of the friction between the brake-shoes and the wheels, tending to retard the rotation of the wheels and thus stop the car. The relation which this bears to the energy stored up in the moving car, provided the "adhesion" of the wheel to the rail is not exceeded, determines the effectiveness of the brake and the length and time of stop. The energy of the moving car consists of two parts—that of the car as a whole due to the velocity of translation, and that of the revolving wheels, due to their rotation, and varies as the weight of the car and as the square of its velocity.

The latter may roughly be taken as 5 per cent. of the energy of translation for 12-wheel cars and as 2 per cent. of the energy of translation for 8-wheel cars. In ordinary calculations, however, this factor is usually neglected, and properly so, because for modern rolling stock the resistances other than as derived from the brakes, such as internal friction, air resistances, flange friction and so on, has been shown by actual experiment to at least equal if not exceed the inertia effect of the revolving parts. Consequently a greater error is made by considering the energy of rotation without at the same time taking into account the resistances to motion which exist due to other causes than the brake-shoes (which, it should be noted, are usually indeterminate and subject to considerable variation) than to assume that these two opposing factors neutralize each other.

The frictional force between the brake-shoes and wheels depends on the pressure acting on the shoes and the coefficient of friction between the shoes and the wheels. In making a stop, therefore (it being assumed throughout that the wheels do not skid), the factors involved, so far as retarding the rotation of the wheels is concerned, are:

1. The total amount of brake-shoe pressure in pounds, commonly called the "braking power."
2. Coefficient of friction between the shoes and the wheels, by which the brake-shoe pressure must be multiplied in order to determine the actual retarding force.
3. The weight resting on the wheels.
4. The velocity of the car.
5. The rotative energy of the wheels.

Only one of these factors can be controlled even partially in service or fixed arbitrarily in designing the brake system, viz.,

the pressure on the brake-shoes. Inasmuch as the wheels must not skid when the weight resting on the wheels is least,—that is, when the car is not loaded,—the light weight of the car must be taken as the basis of calculation regarding brake-shoe pressure, except in the case of some form of " empty and load " brake. Since the " braking power " is, by custom, measured by a scale of percentages wherein 100 per cent. represents a shoe pressure on each wheel equal to that wheel's pressure on the rail, the problem is then to determine and insure the obtaining of the proper relation between the brake-shoe pressure and the light weight of the car.

As pointed out above, the factors involved, such as frictional coefficients, speed, weights, etc., are so subject to variation in service that no theoretical conditions can determine the proper nominal percentage braking power (*i.e.*, the ratio of brake-shoe pressure to light weight of car), which shall best meet average road conditions. This can be fixed only by experiment and experience and is subject to modifications as conditions change or become more thoroughly understood. For example, many years' experience has proven that 90 per cent. braking power for passenger cars gives satisfactory braking effects with a reasonable margin against wheel sliding and sufficient power for service stops. This was determined by the results obtained on the lightest cars. So far as wheel sliding is concerned, a 150,000-pound car braked at 95½ per cent. has practically the same margin against wheel sliding as a 70,000-pound car braked at 90 per cent. But if the percentage of braking power is varied, the uniformity of service braking effect, other factors being the same, is lost. *Therefore, the percentage of braking power determined as a satisfactory maximum for the lightest cars* must be adhered to on all cars, in order to bring about as nearly as possible the uniform results which are necessary for satisfactory service operation.

Having, therefore, chosen a certain percentage of braking power which should be obtained on all cars, it is evident that what actually is obtained, in any given instance, depends on the total leverage ratio and the pressure per square inch on the brake-piston. It will be apparent that all resistances between the brake-piston and brake-shoes, such as release springs, reactions of hanger links, friction of rigging, etc., must necessarily be ignored until the essential factors in the design are determined upon.

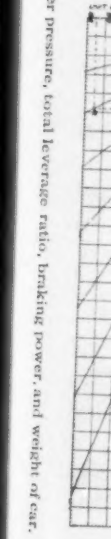

Chart showing relation between size of brake-cylinder, brake-cylinder pressure, total leverage ratio, braking power, and weight of car.

The total leverage ratio is fixed within certain limits by purely mechanical consideration, with regard to piston travel, shoe

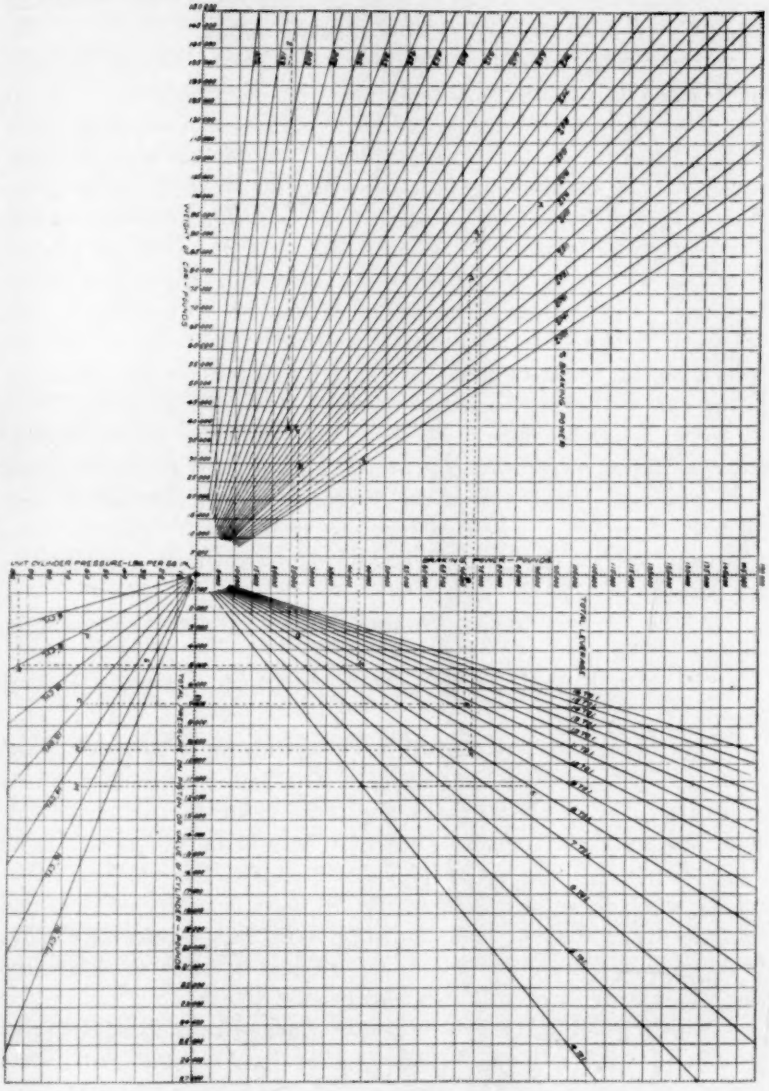

Chart showing relation between size of brake-cylinder, brake-cylinder pressure, total leverage ratio, braking power, and weight of car.

FIG. 23.

clearances, etc., and once the foundation brake rigging is designed, remains always the same.

Hence in any given case the percentage of braking power actually obtained depends entirely on the pressure existing in the brake-cylinder, which varies in practice from zero to the maximum obtained when an emergency application is made.

In designing the brake system for a car, therefore, the leverage ratio and size of brake-cylinder must be so proportioned as to give the required braking power in pounds, with some arbitrarily chosen pressure in the brake-cylinder. Evidently this braking power will be obtained in practice when the brake-cylinder pressure is that on which the design of the brake system was based. For any pressure lower or higher than this, the braking power, in pounds, will be correspondingly lower or higher than the nominal. Furthermore, the actual percentage of braking power (ratio of brake-shoe pressure to weight on wheels) varies not only with the brake-cylinder pressure but also with the condition of the car,—whether loaded or empty.

From a consideration of these conditions it seems evident that it is practically impossible to provide for even an approximate uniformity of brake action on different cars in service by any method of design. The best that can be done is to establish and adhere strictly to the assumed standards upon which such designs are based.

1. The "percentage of braking power" in terms of the light weight of the car.

2. The brake-cylinder pressure upon which this percentage is based.

The former, as has already been stated, must be determined from experiment and experience. The latter must be chosen arbitrarily, but it should have the same value for all brake calculations, in order to insure a common base being universally used and understood. Fig. 23 graphically illustrates the relations existing between these two factors for different weights of cars and total leverage ratios. The question now is, therefore, "What brake-cylinder pressure should be used as a basis in designing the brake systems of all types and classes of cars?"

With a given auxiliary reservoir charged to a standard pressure, and with a given brake-cylinder having standard piston travel, a certain definite pressure of equalization is obtained, which is constant so long as the other factors involved are kept constant.

When an emergency application is made, since a portion of

the air in the brake-pipe or other source of supply is used in addition to that in the auxiliary reservoir, the resulting brake-cylinder pressure is augmented in proportion, and a higher maximum pressure therefore obtained. Evidently its value must depend upon the relation which the supplementary brake-pipe volume bears to that of the auxiliary reservoir and brake-cylinder combined. With equipments now in general use this ratio must necessarily decrease as the size of the car increases because the brake-pipe volume remains practically constant for all sizes of cars, while the brake-cylinder and auxiliary reservoir volumes increase as the size of the car increases. It then follows that where air from the brake-pipe alone is used to augment the brake-cylinder pressure in emergency applications, the emergency pressure thus obtained must vary with the different combinations of auxiliary reservoir and brake-cylinder necessary for different sizes of cars—the gain in pressure from this source over that obtained in full service equalization being greatest with the smallest sizes of auxiliary reservoirs and brake-cylinders.

Hence, in choosing a brake-cylinder pressure on which to base brake calculations, that obtained in emergency, which was satisfactory where the brake-cylinders were of such size that a uniform pressure was obtained in both service and emergency, is now excluded at the outset,—from the stand-point of uniformity,—since in the nature of the case it is not uniform for all weights of cars. This is for the reason that brake-cylinders may vary from 6 inches to 18 inches diameter with correspondingly varying pressures in emergency. And if the braking power desired is based on a brake-cylinder pressure higher than can actually be obtained, then for lower cylinder pressures the brake is not so effective as it might be made, were the braking power based on the pressure actually obtained. The smaller cars which do obtain this pressure, give the calculated braking power in emergency, but the heavier cars cannot, and there is a loss, both in uniformity of emergency action and possible efficiency.

On the other hand, for brake-pipe reductions less than sufficient to produce equalization, the cylinder pressures obtained are uniform, provided the other factors are uniform in value and the pressure at which the auxiliary reservoir and brake-cylinder equalize is supposed to be the same for all combinations of reservoirs and cylinders, with the same initial pressure. To obtain this uniformity it is only necessary to properly proportion the

reservoir volume to the brake-cylinder volume for some standard piston travel. We then have a pressure base which will be constant when the other factors involved have their proper or standard values. It would seem that this is the basis to which all braking power calculations should be referred, for the reason that it is the nearest approach to a uniform and constant pressure obtainable under the wide range of conditions governing this choice. This adds to the standard enumerated on the preceding page, the following:

3. This brake-cylinder pressure must be the equalized pressure on the auxiliary reservoir and brake cylinder.

4. A predetermined ratio between auxiliary reservoir volume and brake-cylinder volume to produce this equalization must be adhered to.

The fundamental steps in designing a brake system for any given car may now be outlined as follows:

Given the light weight of the car the proper braking power per cent. has been established from results of experiment and experience and this enables the total brake-shoe pressure to be calculated.

Mechanical considerations fix the total leverage ratio between certain limits, the maximum and minimum values of which enable a maximum and minimum total brake-piston pressure to be calculated from the preceding.

This total brake-piston pressure depends upon the size cylinder and pressure per square inch used as a basis. The pressure basis to be used should be that agreed upon as a universal standard, for such calculations as this, and, as has already been pointed out, uniformity requires that the *equalization pressure* (50 pounds per square inch), from the lowest standard brake-pipe pressure carried, should be the base chosen.

Having determined the unit pressure, the size of cylinder can be chosen from the standard sizes manufactured to give the desired braking power with a total leverage within the maximum and minimum limits as defined above.

To obtain the desired 50 pounds equalization pressure from the standard 70 pounds brake-pipe pressure with a standard piston travel, is simply a matter of correctly proportioning the auxiliary reservoir volume to that of the brake-cylinder at the piston travel employed as standard.

We then have an auxiliary reservoir which, at 70 pounds in-

itial pressure, will equalize with its brake-cylinder, when this has eight inches piston travel, at 50 pounds, and the brake-cylinder piston is of such an area that the total pressure thus obtained, when multiplied by the total leverage, will give a total brake-shoe pressure equal to the desired percentage of the light weight of the car.

To be sure, in an emergency application, the braking power on all cars will be greater than that used in the design, and the lighter the car the greater the variation between service and emergency braking powers. But such non-uniformity in actual service is bound to obtain, and always has, since an increase to 90 pounds brake-pipe pressure, or a variation in piston travel produces similar results, to say nothing of losses due to leakage, resistances and variations in frictional coefficients. The advantage gained, however, by the method of design outlined is, therefore, in the fixing of a uniform and actually obtainable brake-cylinder pressure, which is necessary for service operations and is one of the most important factors in the calculation to be made.

It may be said in passing that with the more recent types of brake-equipments for passenger service, using a supplementary reservoir volume, in addition to that of a brake-pipe to produce high emergency brake-cylinder pressure, the size of supplementary reservoir used is calculated to give practically uniform brake-cylinder pressures in emergency applications with *all* sizes of brake-cylinders, thus taking advantage of the principle of high pressures for emergency stops and at the same time conforming to the principles of uniformity laid down above, it being a fundamental principle of modern brake design to keep the service equalization brake-cylinder pressure comparatively low, for reasons fully explained elsewhere, and use as high an emergency equalization pressure (as large a supplementary reservoir), as may be desirable.

In the attempt to secure a high emergency brake-cylinder pressure without the aid of the supplementary reservoirs referred to above, the relationship between brake-cylinder and auxiliary reservoir volumes existing in the *original* brake design was gradually lost; the auxiliary reservoir volume being increased slightly, from time to time, as heavier cars, requiring larger brake-cylinders, were equipped. On the lighter equipment the variations thus introduced were relatively unimportant, but in the case of heavy cars, requiring the 16-inch and 18-inch cylinders, it was im-

possible to increase the auxiliary reservoir volume sufficiently to obtain the desired emergency pressure, without at the same time interfering to a marked degree with the proper operation of the equipment in service. Consequently, a compromise was made, so as to obtain as high an emergency cylinder pressure as possible without increasing the service equalization pressure to an extent inconsistent with the proper normal functions of the brake.

By the aid of a supplementary reservoir volume, however, reserved during service operation, but available in emergency applications of the brake, it is now possible to obtain the required increase in stopping power for emergencies and at the same time return to the original volume relationship, the correctness of which has been established by long experience.

These relationships are determined by the following principles, which will be recognized at once as having been followed in even the earliest automatic-brake designs.

(A) For any given arrangement of leverage between the brake-cylinder piston, and the brake-shoes, the "braking power" is directly proportionate to the gage pressure of air produced in the brake-cylinder.

(B) The limitation of the maximum allowable pressure of air in the brake-pipe limits thereto the available pressure in the auxiliary reservoirs.

(C) With this fixed maximum charge in the auxiliary reservoir, the highest pressure obtainable in the brake-cylinder from this single source is that at which the air pressure equalizes between the two. This (absolute) pressure, therefore, equals the product of the initial absolute pressure in, and the volume of the auxiliary reservoir divided by the sum of, the volumes of the auxiliary reservoir and of the brake-cylinder (neglecting all clearance volume, temperature effect, etc.), and the "braking power" is as the corresponding gage pressure.

(D) This pressure of equalization should be limited because its height determines the range of those differences between final auxiliary reservoir pressure and initial brake-pipe pressure, which range affords the control of "braking power" applied.

(E) That while low pressure of equalization limits "full service" pressure, yet small range precludes nicety of control, especially as from the range there must be deducted such initial differences of pressure as are necessary to overcome the inertia and friction of the triple valve parts.

(F) That to afford heightened brake-cylinder pressure for use in emergency another quantity of air is necessary, and if this be, as in all past practice, that contained in the brake-pipe, the resulting absolute pressure will be equal, theoretically, to the maximum absolute brake-pipe pressure multiplied by the volume of the auxiliary reservoir plus the amount of air, in cubic-inch-pounds, obtained from the brake-pipe, this sum then divided by the volume of the auxiliary reservoir plus that of the brake-cylinder, so that the measure of the resulting braking pressure is the gage pressure corresponding to this resulting (absolute) pressure.

Now, it is the interdependence and reactive results of these simple and recognized principles in their combinations together with a corresponding proportioning of leverage between the brake-cylinder piston and the brake-shoes that determine the relative efficiency of a brake design.

From (F) it is seen that if other parts be enlarged the volume of the break-pipe, which is practically the same on all cars, becomes relatively small and the emergency pressure sought is so insufficient that in the equipments for heavy rolling stock resort has been had to enlarged auxiliary reservoirs with a correspondingly heightening of the " full service " pressure (C), and a resulting lessening of the range of control (D).

Again when (C) is heightened while (D) is lowered, the results of the lighter brake-pipe reductions cause magnified effects in the service braking, so that, when it is realized that such range as is possible is lessened by the lack of sensitiveness of the triple valve (E), there is likelihood of roughness of service stops.

Such being the case, it is apparent:

1. That there is a ratio of volume of auxiliary reservoir to that of brake-cylinder that should not be exceeded.

2. That such service pressures as result in the brake-cylinder should be made sufficient by a corresponding proportioning of the leverage.

3. That the volume of each car's part of the brake-pipe should be supplemented by proper means so as to afford the required braking pressure in emergency.

Starting, therefore, with a brake-cylinder of the size *dictated* by the vehicle to be equipped, as already explained, and by a proportioning of the leverage which shall accord with the service required, and assuming that

C equals volume of brake-cylinder, in cubic inches;
P equals service equalization pressure, in absolute units;
R equals volume of auxiliary reservoir, in cubic inches;
a equals absolute initial pressure in the auxiliary reservoir;
r equals permissible range of brake-pipe reductions;

it follows first, from the above definitions, that

$$r = a - P$$

and from (C) above, neglecting clearance volumes:

$$\frac{a \times R}{R + C} = P$$

from which

$$R = \frac{P}{a - P} \times C$$

$$= \frac{P}{r} \times C$$

which may be expressed in the following law:

The proper auxiliary reservoir volume, according to the principles laid down above, is equal to the volume of the brake cylinder determined upon multiplied by the ratio of the service equalization pressure fixed upon as standard to the permissible range of brake-pipe reductions.

Assuming, as in current practice, that P equals 50 pounds per square inch (gage) and a equals 70 pounds per square inch (gage), then we have

$$r = a - P = 20 \text{ pounds,}$$

and

$$R = \frac{P}{r} \times C$$

$$= \frac{65}{20} \times C$$

$$= 3\tfrac{1}{4} \times C.$$

That is, the volume of the auxiliary reservoir should be three and a quarter times the volume of the brake-cylinder. It is plain, however, that the effect of the clearance volumes, leakages, temperature, and other adverse influence will be such that to obtain the desired results in actual service a somewhat higher auxiliary reservoir volume must be used than that found by the above calculations. For example, with the standard 8-inch equipment, an auxiliary reservoir volume of 1620 cubic inches is used, which is about three and one-half times the brake-cylinder volume.

In determining the proper size of supplementary reservoir

(F) to be used a similar reasoning may be used. In addition to the symbols already defined, let

S = volume of supplementary reservoir in cubic inches.
E = absolute emergency equalization pressure.

Assuming for the purposes of calculation that the emergency pressure is the result of the equalization of the brake-cylinder, auxiliary reservoir and supplementary reservoir volume, it follows that

$$\frac{a\,(R+S)}{R+S+C} = E,$$

whence, by proper substitution and reduction, is derived

$$S = \frac{a\,(E-P)}{r\,(a-E)} \times C.$$

While the above expression is interesting as showing the simple relation which exists between the various volumes involved in the typical equipment as we have assumed it, it must be clearly understood, first, that all the additional air supply in emergency is supposed to come from the supplementary reservoir, having taken no account of that vented from the brake-pipe; and second, that in any actual installation similar to that discussed, the equalization is dependent upon the movement of certain valves actuated by spring and air pressures in combination, the resultant effect of which is such that in the actual working equipment the state of affairs is by no means as simple as has been assumed for the typical equipment. Instead of equalization taking place between all the volumes concerned simultaneously, there are time limitations imposed on the rate of flow from the various sources of air supply to the brake-cylinder, so as to derive the maximum possible benefit from the compressed air stored in each. There is also a material modification of these calculated results, due to the processes not being truly isothermal, as assumed, and so on. Proper allowance being made for these limitations, a formula might be derived, in the same manner as above, to completely cover the more complicated conditions, but as only the principles involved are now being considered it is unnecessary to go further into details, particularly as these are accurately determined by experiment.

In the above analysis, as is necessarily the case with all theoretical considerations relative to mechanical apparatus of this character, certain assumptions were made to furnish a basis from which to start. Hence, it should always be remembered that the

formulæ derived must be interpreted, for any given case, in the light of the modification of these primary assumptions which the nature of the installation or the character of the apparatus used, may involve. With this understanding, the above reasoning affords a logical and sound theoretical basis, not only for determining the correct proportions of new types of equipment, but also establishes a criterion, by means of which the shortcomings of incorrectly designed installations may be discovered.

BRAKES FOR ELECTRIC TRACTION SERVICE.

It would hardly be proper to conclude without mentioning the fact that the electric traction service has required even more specialized apparatus than that already mentioned in connection with steam-road service on account of the great variety of conditions under which electric cars operate from the single city street car up to the 8- and 10-car subway and elevated trains, to say nothing of the electric locomotive and multiple unit train service on electric division or steam railroads. It can easily be appreciated that these phases of the subject are of even greater magnitude and requires a greater variety of apparatus and complexity of detail than in the case of steam-railroad service. Consequently, no more can be said at this time than to simply state the fact that the multiplicity of requirements has been anticipated and provided for to the extent that the high standard of efficiency already outlined to you has been maintained without any compromise or failure to meet the requirements of the service. In one particular, at least, the highest type of brakes, for electric service, namely, the Electro-Pneumatic System, affords superior stopping power and service efficiency, since its electric transmission of quick action insures simultaneously and almost instantaneously maximum braking power on all cars in the train, while for service braking, it possesses the maximum flexibility of control, possible only in an electrically actuated brake system. This brake therefore possesses superior features which are particularly noteworthy whether they are considered from the stand-point of the time saved, the increased traffic made possible, or the safety insured. At the present time, this type of equipment appears to be the acme of the braking art, but as past experience has always shown, the same time which brings about changes in operating conditions is also sure to develop new and more efficient means for meeting new requirements.

APPLICATIONS OF CHEMISTRY TO PUBLIC WELFARE.

(Synopsis of address delivered at the Franklin Institute, December 21, 1910, in accepting the Elliott Cresson Medal.)

BY

HARVEY W. WILEY.

PRESIDENT CLARK, MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN: I desire to express my sincerest thanks to the Franklin Institute for the high honor conferred on me. I feel that it is a recognition of the value of the work I have tried to do during the past quarter of a century rather than a personal honor, and therefore it is shared by my faithful assistants without whose help this work could not have been accomplished. I accept the medal and diploma which have just been given, and in doing so it is my duty to set forth briefly some of the salient features of the work for which this signal recognition has been given.

Science is knowledge of the knowable; faith is knowledge of the unknowable. Science is exact, that is, quantitative when it is possible that our knowledge of any subject shall be quantitative knowledge; science is inexact when it is qualitative, that is, when our knowledge of a subject is not definite. Mathematics, astronomy and chemistry are quantitative sciences in that the data on which they are based are capable of exact measurement. Biology is to a certain extent a qualitative science in that our knowledge of it in the very nature of things cannot be exact. A theory must not be confounded with a fact. Theories to be of value must be produced either by a scientific imagination which can look into the unknown and see the relations of things to a certain extent and thus be able to predict properties of bodies or forces yet undiscovered, or a theory may be retrospective, based upon accumulated facts and, reasoning by induction therefrom, explain still other facts that are yet undetermined with exactitude.

Science has often been subdivided into the pure and the

applied, but this subdivision it seems to me is untenable and discriminative. What is known as pure science will perhaps be better designated as unused science, if any science could be deemed as unused; applied science, on the other hand, might perhaps be better named as used science if this designation may be made. In point of fact there is no dividing line between science as such, or potential science, and science in action, or dynamic science. It is inconceivable that any expression of fact or truth could fail of being useful in some way or at some time and therefore the pursuit of knowledge of all kinds when properly prosecuted must end in useful discoveries.

In the application of science to agriculture we have combined both the discovery of new truth and the application of old and new truth. Theories are of little consequence aside from their convenience of classification and arrangement. A man's theory of nature does not affect nature in the least, nor does it have any effect upon natural processes. The aurora borealis exists whether it be due to electrical effects, high rarification or any unexplained emanations, and the procession of the equinoxes continues to change the actual point of the pole irrespective of the theories of what is supposed to produce it. Crops continue to grow regardless of what the theories of plant nutrition may be, and variations continue to be naturally produced in animals and plants irrespective of the theories of heredity or evolution.

In the work over which I have had the honor to preside in the Department of Agriculture, for almost thirty years, we have been troubled very little by theories—we have been confronted always with conditions. The investigations which have been made, therefore, have not been to establish any preconceived notions, but to ascertain as nearly as possible facts in regard to the production of phenomena under observation. One of the first investigations undertaken in the realm of agricultural science was a study of the conservation of and waste of plant food. Long before the present vogue of conservation came into existence we planned and executed important studies in the conservation of plant food. These studies were crystallized in two addresses which I gave, one in 1886 as Vice-President of the Chemical Section of the American Association for the Advancement of Science, on "The Economical Aspects of Agri-

cultural Chemistry," and another as the retiring President of the American Chemical Society in 1893, on "The Waste and Conservation of Plant Food." In the summary of the data in the address on the economical aspects of agricultural chemistry the following statements are made:

Future Food Supply.—Since, with a proper economy, the natural supplies of potash and phosphoric acid, as we have seen, may be made to do duty over and over again, and last indefinitely, the economist who looks to the welfare of the future need have no fear of the failure of these resources of the growing plant. Indeed, it may be said that the available quantities of them may be increased by a wise practice of agriculture based on the teachings of agricultural chemistry.

But with the increase of population comes an increased demand for food, and therefore the stores of available nitrogen must be enlarged to supply the demands of the increased agricultural product. It is certain that with the new analytical methods, and the new questions raised by the investigations of which I have spoken, many series of experiments will be undertaken, the outcome of which will definitely settle the question of the entrance of free nitrogen into vegetable tissues. If this question be answered affirmatively, agricultural science will not place bounds to the possible production of foods. If the nitrifying process does go on within the cells of plants, and if living organisms do fix free nitrogen in the soil in a form in which at least a portion of it may be nitrified, we may expect to see the quantities of combined nitrogen increase *pari passu* with the needs of plant life.

Thus even intensive culture may leave the gardens and spread over the fields, and the quantities of food suitable for the sustenance of the human race be enormously increased. In regarding the agricultural economies of the future, however, it must not be forgotten that a certain degree of warmth is as necessary to plant development as potash, phosphoric acid, and nitrogen.

If it be true, therefore, that the earth is gradually cooling, there may come a time when a cosmic athermacy may cause the famine which scientific agriculture will have prevented.

Fortunately, however, for the human race, the cereals, the best single article of food, are peculiarly suitable to a cold climate. Barley is cultivated in Iceland, and oatmeal feeds the best brain and muscle of the world in the high latitudes of Europe.

It is probably true that all life, vegetable and animal, had its origin in the boreal circumpolar regions. Life has already been pushed half-way to the equator, and slowly but surely the armies of ice advance their lines. The march of the human race equatorwards is a forced march, even if it be no more than a millimetre in a millennium.

Some time in the remote future the last man will reach the equator. There, with the mocking disk of the sun in its zenith, denying him warmth, flat-headed and pinched as to every feature, he will gulp his last mite of albuminoids in his oatmeal, and close his struggle with an indurate inhospitality.

In the closing paragraphs of the address on the waste and conservation of plant food, I say:

> Through the ages of the past, the rich stores of plant food have been steadily removed from arable fields and apparently forever lost. But in point of fact no particle of it has been destroyed. Even the denitrifying ferments described by Springer, Gayen and Dupetit, and Muntz, reduce only to a lower stage of oxidation or restore to a gaseous form the nitric nitrogen on which alone vegetables can feed. But electricity, combustion, and the activity of certain anaerobic ferments herding in the rootlets of legumes and other orders of plants, are able to recover and again make available this loss. . . . .
>
> The fact that a few million years may supervene before the particle that is carried off to-day as waste may return to organic life, shows the patience rather than the wastefulness of nature.
>
> As a result of this general review of the migrations of plant food, the reassuring conclusion is reached that there is no danger whatever of the ultimate consumption or waste of the materials on which plants live. Circumscribed localities, through carelessness or ignorance, where once luxuriant crops grew, may become sterile, but the great source of supply is not exhausted. In fact, as the rocks decay and nitrifying organisms increase, the total store of plant food at the disposal of vegetation may continue to grow. When we join with this the fact that the skill of man in growing crops is rapidly increasing, we find no danger ahead in respect of the quantity of human food which may be produced.

It is evident that plants, like animals, cannot thrive without proper care, and food is just as important in the development of high grade plants and abundant crops as it is in the production of high grade cattle and sheep. The soil was regarded for many centuries as dead matter, containing certain stores of plant food, but one of the first things observed in these investigations which were made was that soil is a living body and as such entitled to have a hygiene and physiology of its own. The study of the soil thus becomes not alone a problem in mineral chemistry but a biological problem of the highest importance and significance. In the Bureau of Chemistry were made the first systematic studies in this country of the organisms of the soil which produce nitric acid, one of the most important elements of plant food.

Elaborate experiments were conducted in a series of pot cultures to establish the conditions of maximum activity of nitrification and the relative nitrifying power of different soils.

samples of which were taken under such conditions as to insure normal bacterial activities. These led to the important observation that the chemical composition of plants when mature was influenced in the most remarkable degree by the environment to which they were subjected, and that the influence of the soil in determining the quality of the plants was far less significant than had usually been supposed.

An extensive investigation was undertaken on the influence of environment upon the composition of wheat and other cereals, upon the production of the maximum amount of sugar in the sugar beet, and upon the distribution and qualities of the best varieties of green sweet corn, cantaloupes and other crops. The plan of investigation followed in these studies is, I believe, original and has now been very closely adopted in Australia and some other countries. Briefly, the plan of study was to distribute the same seed in widely different localities and have these seeds planted and cultivated in as nearly as possible the same manner. After being properly harvested and cared for, the crops were chemically examined and compared with crops grown in the mother State. It is evident that in this way the differences in composition were not due to any inherent properties, that is, due to heredity, but to the forces of the environment under which the crops were produced. Several elaborate monographs have been published on this subject and among these the one of the greatest economic significance is the result of the studies, covering more than fifteen years, on the effect of the environment upon the production of the maximum quantity of sugar in the sugar beet. As a result of these prolonged studies a biological map of the sugar beet area was constructed, indicating by a shaded band stretched from the Atlantic to the Pacific those areas in the United States where the richest sugar beets would be likely to grow. The practical benefit of this study is shown in the fact that many intending investors who were about to place their capital in beet sugar enterprises in unpropitious localities were deterred from doing so by the results of these studies, and thus hundreds of thousands of dollars were saved which otherwise would have been squandered. The most remarkable practical demonstration, however, of the value of such studies from an economic point of view is in the fact that practically every beet sugar factory which has been

successful and which is now operating is located in the shaded belt marked out now almost fifteen years ago. The studies of all the factors in the production of a sugar beet of maximum sweetness has led to the conclusion, based upon indubitable data, that the dominant factor is a long day and a moderate temperature, not varying very much from an average of 70° F. for the three growing months of June, July and August. It is evident, therefore, that a high northern latitude, combined with a proper distribution of water by irrigation or otherwise, is the only place where a sugar beet can be grown at the present time which can compete with European grown sugar.

These are only some of the more important of the many biological investigations which have been conducted in connection with the growth of crops and the increase of the food supply of the country. The activities of the Bureau of Chemistry, however, have not been confined to plant life. I am of the opinion that the highest service of science is to man himself, and that the welfare of the plant and of the animal, from an ethical, moral and economic point of view, may have their highest significance in their relation to the welfare of man. To this end a great deal of the energy which has been expended in the investigations of the Bureau of Chemistry has been directed to problems involving human rights, the health of the people and the honesty of trade.

I cannot undertake in these few moments accorded to me to go into further detail respecting the agricultural and biological investigations in which I have been interested and concerned. I only wish to say finally that to me the most important of the factors to be considered in this matter is the moral one—the duty which is pointed out clearly by these investigations to the farmer, the manufacturer and the dealer to refrain from deception and debasement in the growth, manufacture and distribution of food products. I think it is evident to all that a distinct revival of commercial honesty may be seen everywhere as a result of these studies, not only in the trade in foods, but in all trades. Congress has been led to supplement the food law by enacting a similar law relating to insecticides and fungicides. There is now pending before Congress a bill which regulates the manufacture and sale of adulterated and mis-

branded paints. This bill has passed the House of Representatives. Bills have also been introduced before Congress relating to commerce in general and requiring that the manufacturer and dealer shall not misrepresent or debase the article which he has for sale.

Under the old principle of the common law the purchaser himself was held responsible for investigating the character of the goods he bought and this led to the maxim of the common law of *caveat emptor*. The statute of law, however, recognizes the helplessness of the purchaser in most cases to make such investigations and so under this law the legend has become *caveat vendor*. Especially is this true in respect of those who by reason of a tender age are incapable of looking out for themselves. In the case of infants' foods the duty of the State and municipality is plain. The only artificial food an infant deprived of its natural food should have is pure, fresh milk modified to be as much like mothers' milk as possible. Experience has shown that the death rate of artificially-fed infants can be materially reduced by a pure milk diet. What greater service may a municipality render its citizens than to save the lives of the children? It seems to me that the only immediate solution of the problem is the city-controlled milk supply for sick and motherless children. The city should own its own herd of healthy cows, kept in the best sanitary manner. The milk should be handled by the latest methods of transportation and delivered promptly to the consumer. It should be made an offense of the law to feed a demothered infant under one year of age any food save the pure modified milk. A charge equal to the price of ordinary milk should be made for the municipal milk which should be reserved solely for infants' use.

It seems to me that the most important lesson which is taught by the brief recital which I have given is the relation of scientific development to ethics and honesty. It is not claimed that all scientific men are honest or ethical. The percentage of bad men in scientific circles is probably as great as in any other, but the whole tendency of science is towards the glorification of the truth, and the truly scientific man stands with uncovered head in the presence of every great problem, devoutly praying that his investigations may be devoid of preju-

dice and free from error. That science fails of its purpose which does not have in view the welfare and happiness of man

As is the case with every other means of good so we must expect to see science sometimes prostituted to base ends. There is a Dr. Jekyll chemistry and a Mr. Hyde chemistry. Every protagonist of the unholy will be able to find somewhere a scientific defender. The cause of the corporation against the rights of the individual may be able to find a defender among the men who are supposed most of all to hold the truth in reverent affection. In the courts of justice the chemist and the bacteriologist will endeavor to safeguard their clients from the penalties of law breaking. But the great and overwhelming majority will stand for the right and fight the battles of righteousness. And in most cases where the scientific man appears to be on the wrong side he is more than likely to be perfectly honest in his views. I want to live to see a new emancipation day. That is indeed a glorious day now celebrated that marks the end of African slavery. But the white man is also entitled to his freedom. The thralldom of the dollar must be broken, mercenary interests must loose their hold on humanity. Righteousness and honesty must prevail. Then, and then only, will the new emancipation day come—the celebration of the end of the reign of Greed and Graft.

Duralumin, a New Light Alloy. ROBT. GRIMSHAW. (*The Metal Industry,* viii, 9.)—Duralumin is the name given to a series of light and tough alloys, invented by Herr A. Wilm, of Sehlachtensee, near Berlin. One of this series contains 90 to 95 per cent. of aluminum, and has nearly the same properties as good Bessemer steel, except that its specific gravity is only about 2.8. This metal has great value not only for aviators but also for manufacturers of cartridges. For this manufacture a hardness of 160 at the base is required to prevent expansion with the blow of firing. The hardest alloy of this series reaches 125 in its natural state, which may be increased by cold hammering to 174, taken by the Brinell test. By using one of the hardest of the alloys and treating the metal hot, the hardness is reduced so as to lighten the operations to which it is submitted. For airships the stretch under extension must not be over 8 per cent. Tests show that the new alloy breaks at 62 Kg. per square mm. or 88,000 lbs. per square inch.

THE VALUE OF CERTAIN PAINT OILS.

BY

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THE recent activity of the paint chemist in searching for oils to partly replace linseed oil, has come not only as a result of the present scarcity of the latter commodity, but through a desire to develop a vehicle that will be for certain technical paints even more satisfactory, if possible, than linseed oil.

It is not the writer's intention, however, to encourage the use of so-called substitutes for linseed oil. The market is flooded with them at the present time, and great danger will lurk in their use until their composition is understood or their value determined in a practical way.

The real object of this paper is to present a summary of the results obtained by the writer from a series of experiments on paint vehicles, which may serve to guide other investigators along similar lines of research. The tests outlined herein, although of interest in pointing out the possibilities of the use of many oils other than linseed, are, nevertheless, tentative in nature and subject to confirmation through practical field exposure tests before they are to be accepted commercially.

It is well known that a most desirable feature of paint oils is their ability to set up in a short period to a hard surface that will not take dust, that will stand abrasion and offer resistance to moisture and gases. This drying property is dependent upon the chemical nature of the oil. If it is an unsaturated compound, like linseed oil, rapid absorption of oxygen will cause the film to dry rapidly and become hard. If the oil be of a fully satisfied nature, like mineral oil, for example, oxygen cannot be taken up to any great extent and drying will not take place. The various animal and vegetable oils differ in their power of oxygen absorption to a lesser or greater extent. This difference is referred to by the chemist in terms of the iodine value. The iodine value of linseed oil is approximately 190, meaning that one gramme of the oil will take up 190 centigrammes of iodine.

Soya bean oil which has presented itself as a claimant for distinction in the list of paint oils, is now being imported into this country in large quantities. It is obtained from the seeds

TABLE I.

CHEMICAL CHARACTERISTICS OF SOYA BEAN OIL.

Sample No.	Specific gravity	Acid No.	Saponification No.	Iodine No.	Per cent. of foots
1.....	0.9233	1.87	188.4	127.8	3.81
2.....	0.9240	1.92	188.3	127.2	....
3.....	0.9231	1.90	187.8	131.7	....
4.....	0.9233	1.91	188.4	129.8	....
5.....	.....	....	.....	130.0	....
6.....	.....	....	.....	132.6	....
7.....	.....	....	.....	136.0	....
Average..	0.9234	1.90	188.2	130.7	....

of Soya Hispida, a plant indiginous to Manchuria, but raised extensively in our own Southern States as a cattle food.

The writer has examined a number of representative samples of the oil that have comé into this country, and the results obtained can be seen in Table I.

TABLE II.

IODINE VALUES OF LINSEED OIL AND MIXED OILS.

Sample No.	Straight linseed	Soya, 25 per cent.; Linseed, 75 per cent.	Soya, 50 per cent.; Linseed, 50 per cent.	Soya, 75 per cent.; Linseed, 25 per cent.
1.....	190.3	175.2	160.7	140.4
2.....	189.5	175.9	161.7	140.8
3.....	188.0	175.4	160.3	139.0
Average.....	189.3	175.5	160.9	140.4

It is evident that the iodine value of soya bean oil is the only chemical characteristic that markedly differentiates it from linseed oil. Therefore, in the detection of soya bean oil and its estimation, the iodine values of several samples of mixed oils are given, as being of interest in this connection (Table II).

A series of tests were conducted to determine what drier was the most efficient to use with soya bean oil, and the results of these tests indicated that the percentage of lead or manganese, or of lead and manganese, which gave the maximum efficiency in the drying of linseed oil, gave also to soya bean oil the best results. The methods used in carrying out the tests were the same as on linseed oil, referred to later in this paper.

A definite quantity of oil was placed in weighed friction-top can covers, which were re-weighed after receiving the oil, to determine the amount used for the test in each case. The tin covers containing the oil were then placed in a large box under definite temperature control and humidity, for a certain period. Weighings were made at different periods, and the increases in weight, due to absorption of oxygen, was calculated to percentages.

Table III gives the results obtained. The time of drying was somewhat longer than with linseed oil.

Several test panels were painted with zinc and lead, alone and in combination, using linseed oil, soya bean oil, and mixtures of the two. No driers were used in these paints, as the object of the tests were to determine the drying action of the oils, without driers. The drying of the linseed oil paints was very good in less than two days, while the straight soya bean oil required nearly four days to set up, and was then tacky for a long period. Laboratory tests of a preliminary nature made with mixtures of the two oils, ground with pigments, so far have indicated that a moderate percentage of soya bean oil is not detrimental when used with linseed oil.

The writer has found that a few drops of soya bean oil placed in a porcelain dish will give with a drop of strong sulphuric acid, faint fluorescent yellow and green colors, forming a pattern distinct from the dark-brown begonia-shaped leaf formed by sulphuric acid with pure linseed oil. Many other qualitative tests have been tried to detect the presence of soya oil in admixture with linseed oil. Soya oil seems, however, not to possess the chromogenetic properties of oils, such as cottonseed oil.

Tung oil, or Chinese wood oil, as it is often termed, has been considered heretofore as an oil most valuable in the manufacture of varnishes, but seldom if ever to be used as a paint

oil. As a matter of fact, however, in manufacturing, certain technical paints for the protection of concrete and steel, the water-proofing of structures, and for other purposes, the manufacturer may find this oil, or its products, most useful, and to be prized very highly. Toch, as well as Lewkovitch, have shown

TABLE III.

SOYA BEAN OIL AND LEAD DRYER.

Per cent. PbO.		0.05	0.10	0.30	0.50	0.70	1.00	1.30	1.60
Per ct. gain	1 day..	....	0.07	0.63	1.34	1.05	1.53	0.93	1.35
	3 days.	....	0.07	3.52	4.31	2.75	4.86	4.82	4.12
	5 days.	....	0.09	5.04	6.06	6.09	6.75	6.66	5.52
	12 days.	....	....	6.88	7.54	7.43	7.76	7.32	6.47
	15 days.	....	....	8.84	8.93	8.59	8.81	8.44	7.46
	20 days.	0.05	0.20	9.02	9.08	8.90	9.03	8.65	7.83

SOYA BEAN OIL AND MANGANESE DRYER.

Per cent. MnO_2		0.01	0.05	0.15	0.26	0.30
Per ct. gain	1 day.....	....	....	0.02	0.02	0.01
	10 days....	....	5.06	6.48	6.10	5.97
	20 days....	0.05	9.07	8.80	6.78	6.51

SOYA BEAN OIL, MANGANESE AND LEAD DRYER.

Per cent. PbO.....		0.20	0.30	0.50
MnO_2.....		0.05	0.15	0.25
Per ct. gain.....	1 day.....	3.04	3.77	3.74
	8 days....	5.96	6.43	6.47
	12 days....	6.33	6.78	6.67

that metallic tungates are most excellent driers, and the former paint technologist,[1] has indicated their value for certain special purposes. The high iodine number of tung oil makes it a most rapid drier, even faster than linseed oil, but the soft and opaque film it leaves upon oxidation, makes essential its treat-

[1] Toch: "The Newer Paint Materials," The Decorator, London, Nov. 22, 1910, p. 174.

ment by special processes when it is used either for varnishes or for paints, except in special cases.

The writer has prepared the tungate of lead by precipitating saponified tung oil with lead acetate. This tungate after it has been freed from water, may be fused with a small percentage of colophony and borate to produce a rapid drier that gives a perfectly clear film. Experiments with this drier are referred to later.

Menhaden oil, although of marine-animal origin, has a high iodine value, as the following recent tests will show:

Sample number 1	Iodine, 149
Sample number 2	Iodine, 162
Sample number 3	Iodine, 164
Sample number 4	Iodine, 158
Sample number 5	Iodine, 161

The oil obtained from fresh fish is extremely light in color, but the odor is objectionable, when the oil is heated. This oil is a fairly rapid drying oil, and its composition would indicate that it might possess considerable merit. Toch claims that it is of great value for smokestack paints, and for zinc paints exposed at the seashore. Its content of stearine might account for certain waterproofing properties claimed by producers and would suggest its use in paints for the protection of iron and steel.

Some of the other oils used in these experiments will be considered briefly. Cottonseed oil and corn oil are both light in color, and although greatly inferior to even soya bean oil in their drying action, should merit further investigation.

Rosin oil, the product of the dry distillation of rosin, is dark and viscous. It has a low iodine value, and a high acid number that unfits it for general use as a painting oil.

Sunflower oil is high in iodine number, light in color, but very scarce. There seems to be no reason, however, why the seed should not be grown in larger quantities in this country and the oil produced as a painting oil.

Perilla oil is very high in iodine number, even higher than linseed oil, but it also is very scarce. It is obtained from the Perilla nuts, grown in Manchuria and the East Indies. Its iodine number is 206, but Lewkovitz claims that its drying action is accompanied by a peculiar "dropping" of film. This con-

dition might be overcome by special treatment. The writer has not made any experiments on this oil.

Waste oil, or the mixture of fatty acids, and glycerides obtained from the garbage in large cities, is being produced and used in great quantities as soap oils, but the investigations of the writer on several samples, has shown this product to be of small value as a paint oil. Its use in combination with linseed oil to produce a soft, elastic, water repellant film for paints to protect iron and steel submerged in sea water should be studied.

There are several blown and oxidized linseed and other oils upon the market that are so thick that 50 per cent. of benzine or other diluent is required to reduce them to painting consistency. There are also several debloomed mineral oils which resemble linseed oil only in viscosity and their value should be looked into with great care before they are used.

TABLE IV.

CONSTANTS OF VARIOUS OILS.

	Specific gravity	Iodine number	Acid number	Saponification number
Linseed oil	0.934	188	3	191
China wood oil	0.942	172	5	190
Soya bean oil	0.922	134	2	188
Menhaden oil	0.935	160	5	189
Sunflower oil	0.929	128	4	188
Cottonseed oil	0.923	110	4	...
Corn oil	0.924	117	8	190
Rosin oil	0.989	28	.	...
Waste oil	.....	60	34	...

There are on the market many so-called Japan oils. The base of many of these oils is melted rosin, thinned with some linseed oil and large quantities of benzine. Their use is not to be recommended until practical tests of their value have been made.

A table (Table IV) of constants of various oils was made from recent experiments, the oils being subsequently used for the tests referred to in Table V.

The following drying tests (Table V) were made by painting thin films of oil on glass plates, exposing to the atmosphere, and carefully observing the time of the drying. These tests do not indicate the wearing value of the oils tested, but are

simply criterions of their relative drying values. Although sample No. 2, which is untreated tung oil, dried with Drier X, more rapidly than untreated linseed oil with Drier X, it

TABLE V.

DRYING TEST OF OILS.

Sample		Hours
No. 1	*Pine oil with 10 per cent. Drier X	2½
No. 2	Tung oil with 10 per cent. Drier X	2¾
No. 3	Linseed oil with 10 per cent. Drier X	3
No. 4	Linseed oil.....25 per cent. Soya bean oil...25 per cent. Menhaden oil...25 per cent. Tung oil.....15 per cent. Lead tungate...10 per cent.	3
No. 5	Linseed oil.....75 per cent. Chinese wood oil 25 per cent. with 10 per cent. Drier X	3
No. 6	Linseed oil..75 per cent. *Pine oil....25 per cent. with 10 per cent. Drier X	3
No. 7	Linseed oil.....50 per cent. Menhaden oil...25 per cent. Soya bean oil...15 per cent. Lead tungage...10 per cent.	3¼
No. 8	Menhaden oil with 10 per cent. Drier X	3½
No. 9	Soya bean oil with 10 per cent. Drier X	3½
No. 10	Linseed oil.....80 per cent. Waste oil.....10 per cent. Lead tungage...10 per cent. with 10 per cent. Drier X	3½
No. 11	Linseed oil.....75 per cent. Soya bean oil...25 per cent. with 10 per cent. Drier X	4
No. 12	Linseed oil.....75 per cent. Corn oil.....25 per cent. with 10 per cent. Drier X	5½
No. 13	Linseed oil.....75 per cent. Cottonseed oil...25 per cent. with 10 per cent. Drier X	6½
No. 14	Linseed oil.....75 per cent. Rosin oil.....25 per cent. with 10 per cent. Drier X	10
No. 15	Corn oil with 10 per cent. Drier X	8
No. 16	Cottonseed oil with 10 per cent. Drier X	9
No. 17	Rosin oil with 10 per cent. Drier X	Not dry in 2 day

* Pine oil referred to is not rosin oil but the high-boiling-point distillate of wood turpentine.

is the writer's opinion that the linseed oil would be the more serviceable. The pine oil referred to in these tests is not the pine oil of commerce, but a product of the refining of wood

turpentine. 'Drier X' referred to was a strong lead and manganese linoleate drier.

The only practical field tests made by the writer thus far on the value of oils, other than linseed oil, are those at Nashville, Tenn., where a fence has been erected, consisting of 42 tests of white paints. In these tests pure linseed oil was used, except in formulas 31 to 42.

On these tests there have been placed one formula which has given satisfaction on the various other test fences erected, and this formula has been made up with combinations of linseed oil and other oils. One of the oils tested is called pine oil, a high-boiling-point product obtained from the manufacture of wood turpentine from sawdust. This has a boiling point of over 210° C. as against 150°, the boiling point of ordinary gum spirits. It is almost water white and has the same penetrating qualities as the pure gum spirits, and is almost free from that objectionable odor characteristic of so many low-boiling-point products. When mixed with 50 per cent. linseed oil, this product forms a paint oil of extremely light color, and most excellent properties, producing a semi-flat paint of great whiteness. If exposure tests prove this oil as worthy as the tests thus far show, it would appear to be of great importance to the Southern manufacturers to produce this material in quantity, by fractional distillation of the crude spirits. Its iodine number is high and its oxygen carrying properties are good. Its evaporation leaves a durable film.

The tests referred to on the Southern Test Fence are as follows:

COMPOSITION OF FORMULAS.

No. 31	Corroded white lead	45 per cent.	Ground in pure linseed oil.
	Zinc oxide	45 per cent.	
	Asbestine	5 per cent.	
	Calcium carbonate	5 per cent.	
		100 per cent.	

No. 38—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. soya bean oil.

No. 39—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. corn oil.

No. 40—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. cotton seed oil.

No. 41—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. rosin oil.
No. 42—Same as No. 31 but ground in 50 per cent. raw linseed oil, 50 per cent. pine oil.

Driers.—The problem of drying of oils and their behavior with various siccatives in varying quantity is an interesting one, and, obviously, of considerable importance from a practical standpoint. Unfortunately there is a decided scarcity of reliable literature dealing with the subject for the guidance of those concerned in the manufacture or application of siccative products. Furthermore, when the problem is investigated, it is not difficult to see why this is so.

At a glance, it is evident that a decided obstacle in experimentation on the drying properties of oils, is the difficulty in obtaining identical conditions for comparative purposes. Inasmuch as a multitude of factors, such as uniformity and homogeneity of the driers and the oils themselves, intensity and source of light, temperature, uniformity of application, and many others, play a decisive part in the siccative tendencies of oils, the resources and ingenuity of the chemist engaged in the research are severely taxed.

It is a well-known fact that linseed oil, when applied to a clean surface, such as a glass plate, will undergo oxidation and take up oxygen to the extent of about 16 per cent., forming a hard, elastic, non-sticky product which has been called linoxyn. This material, unlike the oil from which it has been formed, is insoluble in most solvents. Other oils, such as cottonseed, hemp, rape, olive, etc., are more fully satisfied in nature and have not the power to absorb the amount of oxygen taken up by linseed oil. It is said that perilla oil, however, will absorb as high as 20 per cent. of oxygen.

In carrying out the following tests, on the drying of oils, a quantity of pure linseed oil of the following analysis was secured:

Specific gravity at 15° C.	0.934
Acid number	5
Saponification number	191½
Iodine number	188

This oil was distributed into a number of 8 oz. oil sample bottles, and to a series of these bottles was added varying quan-

tities of a very concentrated drier made by boiling oil to 400° C. in an open kettle, with the subsequent addition of lead oxide. The amount of drier added to each bottle varied according to the percentage desired; being calculated on the lead content of the drier, which was very accurately determined by analysis.

There was secured in this manner a series of oils containing varying amounts of lead oxide, and from this lot was selected a certain number of samples which would be representative and typical of paint vehicles now found in the market.

Another series of tests were made by combining with a large number of samples of pure linseed oil as used above, various percentages of a manganese drier made by boiling oil at 400 degrees and incorporating therewith manganese dioxide.

Still another series of tests were made upon a number of oils into which were incorporated various small quantities of lead oxide and manganese oxide together, using the standard driers made in the above manner, all of which were carefully analyzed to determine their contents.

In view of the errors in manipulation that could occur where so many tests were made, it was not deemed advisable, in carrying out the tests, to use glass plates, on which only a minute quantity of oil could be maintained. A much better solution of the difficulty presented itself in using a series of small, round, crimped-edge tin plates about three inches in diameter, such as are used for lids of friction-top cans.

With paints it is impossible to secure films as thin as those presented by layers of oil on glass, nor would it be desirable to secure films of this same relative thickness. For this reason, an endeavor was made to conduct the following tests with films of the same relative thickness as that possessed by the average coating of paint. The drying of the films did not take place in the same short period, nor in the same ratio as with the thin layer that is secured by flowing oil upon glass. The results, however, are more practical, and of greater value to the manufacturer.

The cans were carefully numbered in consecutive order, corresponding to the numbers on the various samples of oil. A very small quantity of oil was placed in each of the can covers, which were previously weighed, and allowed to dis-

tribute itself over the bottom surface thereof. Re-weighing of the covers gave the amount of oil which was taken for each test. The test samples in the covers were all placed in a large box with glass sides, having a series of perforated shelves. In the side of this box as an opening through which a tube was passed, carrying a continual current of air washed and dried in sulphuric acid. Oxidation of the oil films commenced at once, and the amount of oxygen absorbed was determined at suitable periods, by weighing, the increase in weight giving this factor. This test was kept up for a period of twenty days.

A test was also made in the same manner with a current of damp air passing into the box, to observe the relative oxidation under such conditions.

The experiments consumed considerable time and effort. A chart of the results obtained have been made (Table VI), to show the effect of the various driers.

The following outline will present to the mind of the reader the most salient points which have been gleaned from these experiments, and which should give the manufacturer definite knowledge as to the best percentage of oxides to use either in boiled oil, paints or varnishes.

In the case of lead oxide, an increase in the percentage of lead oxide in the oil causes a relative increase in the oxygen absorption, but when a very large percentage of lead has been added, the film of oil dries to a leathery skin.

In the case of manganese oxide, the increase in oxygen absorption on the first day is much more pronounced than is the case with lead oxides. Furthermore, the oxidation of manganese oils seems to be relative to the increase in manganese up to a certain period, when the reverse of this law seems to take place, and beyond a certain definite percentage of manganese, added percentages seem to be of no value. It was furthermore observed that the films dry to a more brittle and harder skin than is the case with lead oxide. The oxygen absorption with oils high in manganese has been noticed to be excessive, and the film of oil becomes surface-coated, drying beneath in a very slow manner, a condition that often leads to checking. The critical percentage where the amount of manganese appears to be most propitious and renders the greatest efficiency seems to be 0.02 per cent. This critical percentage,

TABLE VI.

LINSEED OIL AND MnO_2 (Manganese) DRYER—TEST NO. 1.

Per cent. MnO_2		0.02	0.05	0.15	0.25	0.35	0.45	0.55	0.70	1.00
Per cent. gain.....	1 day..	0.08	0.11	0.16	....	3.21	3.46	3.27	3.01	2.76
	2 days.	0.16	5.88	4.48	....	3.63	4.01	3.70	3.51	3.18
	3 days.	0.21	6.79	4.61	....	3.83	4.31	....	3.91	....
	4 days.	....	....	4.64	....	....	....	....	....	....
	5 days.	3.01	6.84	....	....	4.13	4.68	4.19	3.91	3.99
	6 days.	8.00	....	4.88	....	4.37	....	4.51	4.32	4.13
	7 days.	8.58	6.92	4.90	....	4.48	....	4.61	4.52	4.23
	8 days.	9.06	....	5.03	....	4.55	5.23	4.77	4.62	4.44
	9 days.	....	....	5.12	....	4.63	5.40	4.94	4.79	4.51
	10 days.	9.07	6.89	5.18	....	4.81	5.47	....	4.98	4.73
	11 days.	9.15	7.03	....	....	....	....	....	....	....
	12 days.	....	....	....	....	4.98	....	5.45	5.33	5.22
	13 days.	9.22	7.17	....	....	5.25	6.00	5.60	5.42	5.33
	14 days.	9.25	7.18	5.55	....	....	....	....	....	....
	20 days.	....	7.21	5.81	....	5.84	6.70	5.94	5.84	5.77

Above percentages of drier reckoned to metallic content.

TABLE VII.

LINSEED OIL AND MnO_2 (MANGANESE) DRYER—TEST NO. 2 (CHECK).

Per cent. MnO_2		0.02	0.05	0.15	0.25	0.35	0.45	0.55	0.70	1.00
Per cent. gain	1 day..	....	3.12	4.42	3.86	....	3.19	2.98	3.27	2.56
	2 days.	....	6.15	4.73	....	....	3.51	3.28	3.70	2.96
	3 days.	0.28	6.29	....	4.12	3.72	....	3.39	3.71	3.15
	4 days.	3.83	6.32	4.75	4.21	3.87	3.61	3.58	4.05	3.43
	5 days.	6.64	....	4.84	4.23	3.94	3.73	3.65	4.21	3.56
	6 days.	8.61	....	4.87	....	4.08	3.81	3.78	4.35	3.73
	7 days.	9.07	6.35	5.00	4.41	4.18	3.91	3.85	4.54	3.87
	9 days.	9.25	6.39	5.16	....	4.44	4.11	4.21	4.63	4.26
	11 days.	....	....	....	4.63	4.59	4.36	4.31	5.07	4.46
	16 days.	....	6.43	5.30	4.91	4.83	4.72	4.71	5.40	4.87

TABLE VIII.

LINSEED OIL AND PbO (LEAD) DRYER.

Per cent PbO.		0.00	0.05	0.10	0.30	0.50	0.70	1.00	1.30	1.60	1.30	1.60
Per cent. gain..	1 day..	0.042	0.049	0.092	0.058	0.066	0.062	0.062	0.079	0.039	0. 14	0.72
	2 days.	0.098	0.104	0.153	0.116	0.158	.....	0.194	4.83	4.79	5.27	6.11
	3 days.	0.128	0.159	0.170	0.137	0.279	0.185	7.11	8.60	5.35	7.89	8.28
	4 days.	0.164	0.214	0.206	0.178	.....	4.07	7.39	9.55	8.53	7.93	8.68
	5 days.	0.176	.....	0.306	.....	0.340	7.60	7.47	9.87	8.78	8.18	....
	6 days.	0.188	0.231	.....	0.243	0.472	9.36	7.64	10.01	9.00	8.24	9.09
	7 days.	0.206	0.251	.....	0.253	1.080	10.06	....	10.14	....	....	....
	8 days.	0.212	0.253	.....	0.280	4.80	10.38	7.70	10.22	9.05	....	....
	9 days.	0.226	0.291	0.306	0.331	7.36	10.41	7.73	10.23	9.07	....	....
	13 days.	0.327	0.428	0.510	0.674	11.01	10.67	7.91	10.48	9.29	8.62	....
	15 days.	0.466	0.455	0.650	2.41	11.05	.....	7.92	10.50	9.30	....	....
	20 days.	0.521	1.08	1.78	8.76	11.25	10.67	7.98	10.52	9.36	....	....

TABLE IX.

LINSEED OIL AND PbO (LEAD AND MnO_2) (MANGANESE)—COMBINATION DRYER.

Per cent. PbO		0.1	0.3	0.5	0.7	0.9	1.1	1.4
Per cent. MnO_2		.005	.015	0.025	0.35	0.45	0.55	0.7
Per cent. gain....	1 day.....	0.026	0.061	0.055	0.022	0.16	0.11	3.06
	2 days....	0.094	0.087	0.143	0.16	5.21	6.28	3.37
	3 days....	0.118	.....	0.17	4.23	7.63	8.31	3.74
	4 days....	.....	0.11	0.23	7.36	8.87	9.20	4.02
	5 days....	0.120	0.12	0.29	9.04	9.13	9.37	4.17
	6 days....	0.17	0.13	1.44	9.88	9.26	9.51	4.34
	7 days....	0.21	0.18	4.65	10.11	9.28	.....	4.45
	11 days....	0.30	0.26	10.03	10.35	9.61	9.85	5.11
	12 days....	.....	.....	.....	10.45	9.66	.....	....
	13 days....	0.35	0.54	10.37	10.51	9.67	10.03	5.33
	18 days....	0.49	3.43	10.38	10.62	9.68	.....	5.73

as it may be termed, should not be exceeded, and any added amount of manganese has the effect of making the film much more brittle and causes the so-called "burning up" of the paint. The loading of paint with drier and the bad result therefrom, may be explained to some extent from the above results.

In the same way with lead driers, excessive amounts of lead oxide seems to have no beneficial effect on the drying of an oil, and when the percentage which seems to be the most beneficial, namely 0.5 per cent. lead oxide, is exceeded, the film is apt to become brittle.

Oils containing lead oxide driers are less influenced in their drying tendencies by conditions of moisture in the atmosphere than oils containing manganese, but frequently, however, the former dry much better in a dry atmosphere. As a general rule, varnishes rich in manganese dry more quickly in a dry atmosphere, while those containing small quantities dry more quickly in a damp atmosphere.

It was furthermore noticed in these tests that sulphuric acid, placed in dishes on the bottom of the large box in which the samples of oil were drying, were discolored and turned brown after several days, showing that the acid had taken up some material of a volatile nature that was a product of the oxidation.

Another curious feature of these tests was the development of a peculiar aromatic odor which was given off by the oils upon their drying in dry air. When the oils were dried in moist air, a rank odor resembling propionic acid was observed, and this led the observer to believe that a reaction was effected by the absorbed oxygen, that caused the glycerin combined with the linoleic acid as linolein to split up into evil-smelling compounds. It has been suggested that the oxygen first attacks the glycerin, transforming it into carbonic acid, water and other volatile compounds, which are eliminated before the oil is dried to linoxyn. Toch,[2] however, has shown that the drying of linseed oil gives off only very small percentages of carbon dioxide. Mulder has observed that in the process of linseed oil being oxidized, glycerin is set free, which becomes oxidized to formic, acetic and other acids, while the acid radicals are

[2] Toch: The Chem. and Tech. of Mixed Paints, p. 89. D. Van Nostrand, N. Y.

set free and are converted by oxygen into the anhydrides from which they pass by further oxidation into linoxyn.

The theory of auto-oxidation of linseed oil has been very ably treated by Blackler, whose experiments indicated that during the drying process the slow absorption of oxygen was, at a critical period, followed by a rapid absorption which he attributes to the presence of peroxides which accelerate oxidation. The materials produced by this peroxide formation may act as catalyzers and accelerate the formation of more peroxide. Lead and manganese oxides may also be oxidized to peroxides by the action of oxygen and in this event might act as very active caralyzing agents or carriers of oxygen. Blacker's statement that the presence of driers do not increase, but have a tendency to decrease the initial velocity of oxygen absorption, has been confirmed by these experiments, but it has been noticed throughout the tests that the driers have an accelerative action at a later period.

Some most interesting results were secured by dipping extremely fine copper gauze into linseed oil, and then suspending the gauze in the air. The adhesion of the oil to the copper caused the formation of films between the network, and remarkable drying action was observed. The copper or any superficial coating of copper oxide which may have been present on the metal, undoubtedly effected the result to some extent. It has been found that metallic lead is even more efficient than copper in this respect, but this may be due to the action of free acid in the linseed oil, forming lead linoleates, products that greatly accelerate drying. Another interesting experiment was made by taking pieces of gauze cloth and immersing in linseed oil. After the excess oil had been removed, by pressing, the cloth was again weighed to determine the amount of oil used for the experiment. The increase in oxygen absorption in this case was very rapid and the result obtained confirmed the results in the other experiments.

In order to secure a more evenly distributed state of the oil, tests were conducted by saturating pieces of stiff blotting papers and after exposure, weighing as usual.

The influence of light on the drying of oils is unquestionably a potent one. The practical painter knows that a certain varnish will dry quicker when exposed to the light than when in the dark.

Chevreul was one of the first pioneers in this field of research to observe the effects of colored lights on drying, and he claimed that oil exposed under white glass dried more rapidly than when exposed under red glass which eliminates all light of short wave lengths.

Genthe obtained interesting results in the drying of oil submitted to the effect of the mercury lamp. Oxidation without driers was effected probably through the formation of peroxides. In commenting on this subject, Blacker[3] gives a description of the use of the Uveol Lamp, which is similar to the mercury lamp, but has instead of a glass casing which cuts off the valuable rays, a fused quartz casing which allows their passage.

In the boiling of linseed oil, by certain processes the oil is heated to 250 degrees and manganese resinate is incorporated therein. It goes into solution quite rapidly. In other processes the oil is heated to 400 degrees or over, and manganese as an oxide is boiled into the oil. Although it is unsafe to say that a small percentage of rosin such as would be introduced by the use of resinate driers, is not harmful, yet it appears that this process should give a good oil, inasmuch as it has been found that no matter whether the manganese is added to the oil, as a resinate, borate or oxide, practically the same drying effect is noticed in every case where the percentage of manganese is the same. It is the opinion of some, however, that the resinate driers are not as well suited for durability as oxide driers. However, if a boiled oil is found to contain on analysis a small percentage of rosin (less than 0.5 per cent.) it should not be suspected of adulteration. Practical tests, however, should be made with such oil along with an oil made with an oxide drier, before pronouncing on their relative values. Inasmuch as the addition of certain driers to linseed oil lessens the durability of the film, it is more practical to use the smallest amount of drier that will serve the purpose desired, that is, set the oil up in a paint to a hard condition which will not take dust and which will stand abrasion.

The results of this investigation would indicate that when lead or manganese linoleates are used, the most efficient results may be obtained with 0.5 per cent. lead or with 0.05 per cent.

[3] M. B. Blacker: "The Use and Abuse of Driers," P. and V. Society, London, Sept. 9, 1909.

manganese or with a combination of 0.5 per cent. lead and 0.02 per cent. manganese.

Until more definite results have been obtained with the *tungates*, which will probably prove of exceptional interest as driers, the above driers will probably be used to the greatest extent.

An Enormous Anchor. (*La Nature*, No. 1948, 130.)—In the Engineering and Machinery Exhibition opened in September at Olympia in London, there is to be seen an enormous ship's anchor which was forged by N. Hingley and Sons, of Dudley, for the "Olympic," the new giant White Star steamer. It weighs 15 tons, is nearly 20 ft. long, and its greatest thickness is 10 ft. The shank is 4 ft. 6 in. thick. It is furnished with a chain of three links each weighing 880 lbs. Twelve horses were required to drag it from Paddington to the exhibition. Another attraction is offered by Messrs. Siebe, Gorman & Co., in the demonstration of its new helmet which allows a man to plunge into water, or through flames or through noxious gases, with impunity. Men provided with this helmet walk at the bottom of a huge vat, filled with water, with glass sides, which allow their least motion to be seen clearly. Their only communication with the outside world is a telephone wire, through which they converse with the spectators.

Crystal Forms which are Stable only at High Pressures. A. SKRABAL. (*Zeit. Phys. Chem.*, lxxiii, 171.)—Tammann has stated that at present no rules can be formulated as to the separation of crystal forms of varying stability and that Ostwald's theory of successive reactions, when so applied, leads to conclusions at variance with the facts. The author believes that his statement of Ostwald's rule that the stability of thermal products is in inverse ratio to the speed of the reaction is in accord with the facts of crystallization. Hence the formation of diamonds by the crystallization of carbon from molten cast iron would be the result of rapid cooling, while graphite would result from slow cooling.

Boroid, a Substitute for Celluloid. ANON. (*Electrician*, lxv, 533.)—A new substance named boroid has been found in commerce recently, which is completely noninflammable. Its use as an insulator and especially as a substitute for celluloid in cinematograph films is to be recommended. On account of its noninflammability its superiority to celluloid for cinematograph films is beyond question.

THE STRETCHING OF A CONDUCTOR BY ITS CURRENT.

BY

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TEXT-BOOKS and treatises on physics teach about the mechanical forces which exist between neighboring conductors in which currents flow and between such conductors and a magnet, as these important forces are the basis of the ordinary electric motor and dynamo and explain other electrical motive devices. But they do not teach about any mechanical forces in the conductor itself produced by its own current, when the conductor is removed from all other circuits or magnets. It is not meant hereby that such internal forces were never thought of or that they never have been mentioned in the more obscure literature; it is believed to be a fact, however, that the usual treatises and text-books do not mention, describe or discuss them, and that therefore the average student has no knowledge of them, hence would not consider them in his subsequent practical work. In the opinion of the writer, however, the modern student ought to be prepared to deal with such new forces when he meets with them in new problems. In the more usual problems of engineering, such internal forces may no doubt be neglected; but when the currents become very large, as in some electric furnaces, or in short circuits, forces which ordinarily are negligibly small, may become quite formidable, particularly in liquids which will yield to even small forces, hence in molten masses in electric furnaces.

One such internal force was recently discovered by the writer and was found to be quite formidable, so much so that it placed a serious limit to the current which can be passed through a conductor under certain conditions; if there is one such formerly unknown force, why could there not be others also.

The purpose of the present article is to give certain reasons which tend to show that a force lengthwise to a conductor ought to be produced by the current flowing through it; and to describe some experiments, which are believed to be new, which show that such a force exists. It acts as an internal force which tends to

stretch and lengthen the conductor, and therefore does not move it as a whole like an external force would; external movements can, however, be produced by it just as the internal forces in a stretched rubber band can produce external motions.

A noted physicist recently said to the writer that no force in the direction of the conductor was known, and that it would be wonderful if one were found to exist. While the former may be true, the writer does not see why its existence would be wonderful; the other internal force mentioned above was entirely unsuspected only a few years ago, yet now that we understand it, its existence does not appear wonderful. Concerning electromagnetic forces in general another noted physicist recently said, "The whole field is one of great mystery and is as yet only glimpsed at, so far is it from being comprehended."

The following eight observations or deductions led to the belief that such a stretching force exists.

a. By the internal forces producing the now well-known "pinch phenomenon" referred to above, the current tends to contract the cross section of the conductor; when the latter is solid, this force cannot manifest itself and was therefore not noticed before; but in a liquid, which readily responds to forces, it becomes very evident, contracting the conductor at its electrically weakest spot, and if strong enough it may even cause actual rupture. This has been described in detail[1]; the only feature of importance in the present discussion is that when a current passes through a conductor it produces radial forces which tend to force the outside of a conductor to the middle even to the extent of completely severing it. This force, like most other electromagnetic forces, is explained to act perpendicularly to the direction of the current; it has become a habit to explain new phenomena by means of such transverse forces because they are familiar to us.

It is a fact, however, that when a conductor contracts in cross section under this radial force, the material of the conductor also moves lengthwise to the conductor somewhere near the central axis, and with considerable force. This flow of the material is

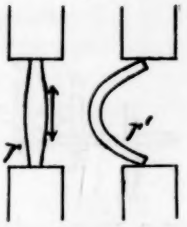
[1] A Practical Limitation of Resistance Furnaces; the "Pinch Phenomenon." Trans. Amer. Electrochem. Soc., 1907, vol. xi, p. 329. The Working Limit in Electrical Furnaces Due to the "Pinch Phenomenon." Trans. Amer. Electrochem. Soc., 1909, vol. xv, p. 255.

about as shown in Fig. 1, which represents a lengthwise vertical section of a liquid conductor carrying a current. One is therefore justified in saying that the conductor acts as though it were being stretched lengthwise, thereby piling up the material at the ends of the tank, which causes it to flow back again into the hollow or pinched part.

It is true that this phenomenon may be completely and perhaps more satisfactorily explained on the assumption of only transverse, radial forces, the horizontal flow being then due merely to the squeezing action of this radial force causing the liquid to flow lengthwise in the same way as it would in a rubber tube filled with water and squeezed by the hand. It is known, however, that most electrical phenomena can be explained correctly in two or more different ways; why then should not this one be capable of an explanation on the assumption of a longitudinal stretching

FIG. 1.

FIG. 2.



force instead of a transverse compressive one. Until the former can be disproved by an experiment or by a satisfactory argument, it cannot be said to be an incorrect or unallowable assumption.

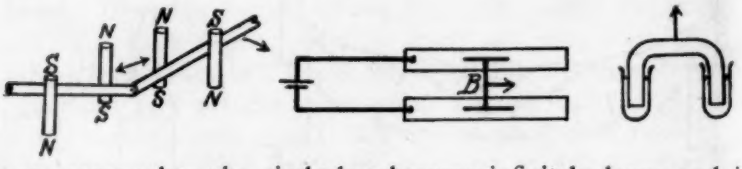
b. The second observation which led to the belief of the existence of a stretching force is the electric arc. When horizontal it forms an arch (whence its name) as though the arc itself, which is a perfectly flexible conductor, were stretching itself, often to the extent of rupture. This is usually explained as being caused by heated air currents, which no doubt is true in part; but does it not also do so when the arc is between vertical electrodes; all the diagrammatic pictures of vertical arcs in the older books show it so. The flickering of an arc is often caused by the arc itself wandering about where it has more room to stretch out and it sometimes even crawls up the side of the electrode, as though it were trying to lengthen itself. In this respect an arc acts like a compressed rubber rod *r*, Fig. 2, which tends

to stretch itself, and if it can do so this stretching force tends to make it take the position r'.

c. The third deduction is illustrated in Fig. 3, which represents in perspective a bent current-carrying conductor flexible at the corner. The encircling magnetism produced by the current may be represented by the four small magnets as shown. The nearer ones will repel each other more than the others, thus exerting a force tending to straighten the conductor; when straight, the repelling force of these two magnets becomes equal to that of the other two and the straightening action therefore ceases, but the forces which did it *still exist,* hence tend to stretch the straight wire.

This is also shown in the well-known experiment of a circular ring of mercury which becomes larger and larger by the action of the current in it, it tends to expand; a tendency to straighten itself would cause such an expansion. Why should we say that this

FIG. 3. FIG. 4. FIG. 5.



force ceases when the circle has become infinitely large and is therefore a straight conductor, especially when we know that it will then tear itself to pieces by the pinch effect, if the current is great enough. In an induction furnace this expanding force is said to become so great at times that one can see the bottom of the circular crucible, the metal being forced radially up against the inner side of the outer wall, as if by centrifugal force.

d. A fourth observation is Ampere's well-known trough experiment shown in Fig. 4, in which a bridge conductor *B* floating on the two mercury troughs, is moved as shown as though the conductors tried to become longer. This will be referred to again below.

e. A fifth deduction is that, as like magnetic lines of force repel each other, and as every current-carrying conductor is encircled by like circular lines of force, these lines must repel each other in the direction of the axis of the conductor, hence produce a stretching force.

f. A sixth deduction is based on the result found by the writer nearly nineteen years ago,[2] that the quantity of magnetic flux produced by an ampere in every centimetre of length of conductor is a constant, assuming no iron, no neighboring conductors or magnetism and a filamental conductor. If, therefore, a conductor be stretched to say double its length (which is possible if it is a liquid, or by means of a sliding contact), the current remaining constant, there will be produced twice the flux. The magnetic flux will have been increased in direct proportion to the lengthening of the conductor.

All experiments with movable circuits and magnets seem to show that that motion will always tend to take place which will increase the magnetic energy of the combination; the mechanical forces will therefore be such as would bring about those motions. As lengthening a conductor increases the magnetic flux, it indicates that there exists a force tending to lengthen it.

Stretching a current-carrying conductor should therefore produce a counter e.m.f., as in a motor; the overcoming of this counter e.m.f. by the source of current represents some mechanical work set free, in this case the lengthening of the conductor. Conversely, compressing a current-carrying conductor should generate an e.m.f., hence be a conversion of mechanical into electrical energy, as in a dynamo.

g. A seventh observation is that shown in Fig. 5. A U-shaped copper bar placed into two mercury-cup terminals will be forced up out of the cups with considerable force, when the current is strong enough. This might be said to be a direct consequence of Ampere's trough experiment shown in Fig. 4.

h. The eighth deduction is from a recent statement by Dr. C. P. Steinmetz,[3] that "mechanical forces are exerted only where the inductance of the circuit changes with the mechanical motion which would be produced by these forces." The lengthening of a conductor increases its inductance (see *f* above), hence if the converse of the above statement is true, the mechanical force of stretching the conductor should be exerted because the induction changes with the lengthening which would be produced by this stretching. This deduction is similar to that in *f*.

[2] Ampere-Centimeter, a Measure of Electromagnetism. Jour. Franklin Inst., vol. cxxxiv, p. 69. Elec. World, May 28, 1892, p. 363.

[3] Proc. Am. Inst. Elec. Eng., Dec., 1910, p. 1916, bottom.

All these eight observations or deductions show that the existence of such a stretching force is to be expected. This term "stretching" is here used in preference to "axial force" because the latter does not imply any particular polarity of motion, while the former term shows that the force acts in two opposite directions so as to straighten and lengthen the conductor but not to move it bodily; of course when one end is fixed, the other would then move bodily. The term "tensile strain" might be used, but it implies external forces, while the manifestations of this stretching appear as an internal force like in the pinch effect, even though both might be explained by the action of the external encircling magnetic flux.

The difficulty in differentiating beyond question such a stretching force from all others, lies in the fact that the action in almost every conceivable combination of circuits may generally also be explained by the older laws, although sometimes it may require some skilful juggling to do so. But even assuming that it were possible to explain all known actions by the older laws, yet if a stretching force also explains them all, and it seems to do so without exception, then why not use it in preference to the others. It is far simpler to understand; the reason for its existence (namely the mutual repulsion of the encircling lines of force) is easily grasped by a student; a single, simple force will then explain numerous different phenomena, which now require a number of different laws to be learned parrot-like, because there is no apparent reason for them; and in general it greatly simplifies the teaching of some of the various electrical motive devices and might even lead to practical applications which would not have been suggested by the older laws.

It might be better still to explain all such phenomena by the simple statement that a magnetic line of force always tends to contract, that it tends to repel a neighboring line of force of the same polarity, and to attract one of opposite polarity. A conductor with a current may then be likened to a wire surrounded by stretched rubber bands like umbrella rings, which are also crowded together laterally; their contraction produces that which corresponds to the pinch effect, and their lateral expansion that which corresponds to the lengthening effect. The stretching of a current-carrying conductor then follows as a consequence, if it is true, as it seems to be (although difficult to demonstrate directly)

that a line of force is rigid with the material of the conductor carrying the current which produces it.

The writer has frequently called attention to the fact that it is wrong to say, as is so often done in text-books, that like currents attract and unlike repel, as it is not the currents *per se* but the material of the conductor which is attracted and repelled, for otherwise Ohm's law would not hold for large conductors and the pinch effect would then not exist; this distinction is sometimes very important.

So it seems equally wrong to say that like lines of force repel and unlike attract, when it seems to be a fact that it is the material in and about which these lines of force are generated, which is moved or affected by those forces. In that case this stretching force is a consequence; so is the pinch phenomenon. It is admitted that the conception of these relations of magnetic lines of force to each other in space is very useful to the mathematical physicist and enables him to deduce very valuable conclusions; but it is also true that the other conception is a very convenient one in practice, namely that every line of force has its origin in some material body and that whenever any of these lines external to it are changed in their position by some force, that force will be felt on that material body. When the disturbing force consists of two equal and opposite ones, no resultant action would be felt by the material, but this does not disprove the original contention. Such a conception would greatly simplify our understanding of many phenomena and hence also the teaching of the student.

There is another parallel case in induction to which the writer recently called attention and which he demonstrated.[4] It is that another one of our former conceptions, so often taught, is wrong; namely, the statement that lines of force cutting a *circuit* will generate an e.m.f. It is not the circuit *per se* but the material of that circuit which must do the actual cutting; if the circuit cuts them but the material does not, there will be no induction; this was demonstrated beyond question.

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[4] A New Factor in Induction; the "Loop" *vs.* the "Cutting Lines of Force" Laws. Elec. World, Mar. 14, 1908, vol. li, p. 559. An Imperfection in the Usual Statement of the Fundamental Law of Electromagnetic Induction. Trans. Amer. Inst. Elec. Eng. 1908, vol. xxvii, part 2, p. 1341.

If, therefore, these forces act on the material, as was shown in the pinch phenomenon in the case of the attraction of like currents, and was shown in the writer's induction experiment in the case of the cutting of lines of force, then why should we not expect the same law to be true in the case of magnetism; it would seem to be unreasonable not to do so.

The following experiments, which are believed to be new, all indicate the existence of this stretching force; it is by no means a small force when the currents are large. Moreover several of them show that some of the former teachings have been wrong and must now be modified and corrected.

In Fig. 6, *a* and *b* are semicircular troughs of mercury. *B* is a pivoted bridge piece connecting the two troughs and free to move around its pivot. The alternate ends of the troughs are connected to a source as shown. The mercury parts of the circuit in both troughs become longer by the clockwise motion of the bridge; hence if the current lengthens its conductor it ought to move the bridge clockwise. It will be found to do so and the force was so great as to sometimes throw the bridge off its pivot.

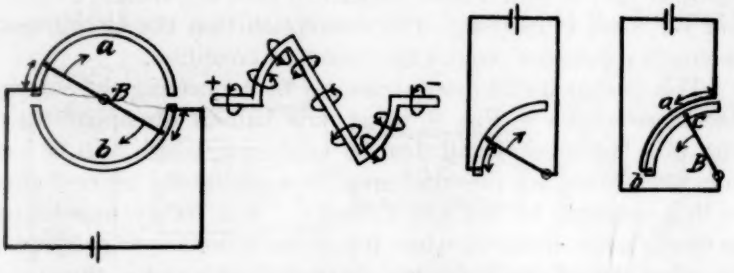
This lengthening is independent of the direction of the current, hence would therefore take place equally well with alternating current. Moreover the force seems to be equally strong for all positions of the bridge; hence is independent of the length of the conductor. This was, however, not measured accurately. Theoretically it seems that when free from all external influences, it should be independent of the length and directly proportional to the square of the current. Moreover the stretching should continue indefinitely, and in this respect it is different from the stretching of a rod strained by compression.

It will be seen that this is not Ampere's classic experiment; in the latter there was no lengthening of the circuit; moreover his circular current was a coil, thus making the whole circular space the equivalent of the end of a magnet, while in the present experiment the motion seems to start with the same force when the circular circuit begins to be formed, as it has later, hence seems to be independent of the length and therefore of the magnetic flux formed by the circular part of the circuit; and the currents in the circular part are not in the same direction around the circle. Furthermore in Ampere's experiment the current in the bridge piece flowed out radially from the central pivot, therefore

in the opposite direction in half of the bridge piece to that in this experiment. Ampere's experiment is the fundamental principle of what is now known better as the disk unipolar machine.

The action in Fig. 6 might be shown pictorily as in Fig. 7. In this the magnetic flux encircling the conductor is represented by lines of force; for the same current there should be a constant number of these lines per inch of circuit; by the lengthening of the mercury parts of the conductor some new lines of force have therefore been produced. They must not be assumed to come from some other part of the circuit, for in the rest of the circuit they remain as they were; the new ones have been created and are therefore to be added to the others; their generation must produce a counter e.m.f. It is the tendency to produce this new

FIG. 6. FIG. 7. FIG. 8. FIG. 9.



flux, or magnetic energy, which causes the lengthening; if none is produced, there will be no tendency to lengthen.

It is not denied, however, that the present experiment shown in Fig. 6 might also be explained by the known action of two currents making an angle with each other; but it is not believed that it had been so devised before that there was a direct lengthening of the circuit. Moreover, when the ends of the bridge piece were bent nearly horizontally in arcs over the mercury troughs for about the distance equal to the radius, and then had their ends dip into the mercury, the action seemed to be just the same, even though the two currents which make an angle with each other were then much farther apart than before. This would indicate that the angular motion was not the true explanation of an apparent stretching, but that on the contrary, a real stretching was the true explanation of the apparent angular motion.

Ampere's trough experiment Fig. 4, and the expansion of a

circular ring, as mentioned above under *c*, have formerly been explained by saying that every circuit tends to expand so as to include as great an area as possible. If this were the true explanation of the movement, it would follow that there ought to be no motion if thereby the area of the circuit is not increased. While if the true explanation is the stretching of the conductor, the circuit should go on expanding even if the area is not increased thereby.

The foregoing test, Fig. 6, showed the former to be wrong and the latter right; hence it differentiates between these two and shows that the teaching of the former should cease. It will be noticed that no matter which way the external return wires are placed, the motion of one-half of the bridge piece will decrease the total area enclosed by the whole circuit, exactly as much as the other half will increase it, hence this area will remain constant, and yet there is motion. The conception that the circuit tends to lengthen does not require this incorrect condition.

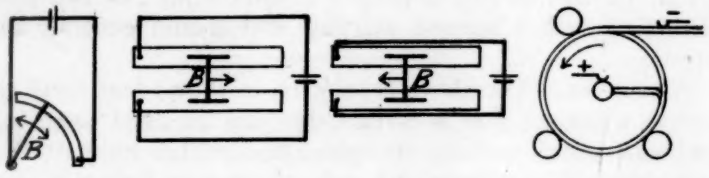
This is shown still more strikingly by connecting the external circuit, as shown in Fig. 8, using only half of the apparatus of Fig. 6. The motion will then be as shown, which will be seen to actually diminish the total area, thus giving the reverse effect to that required by the older theory. The rotary motion will be in the same direction when the connections are transferred to the other arm of the bridge and its trough; this causes the area to increase. In both cases the conception of the lengthening of the circuit predicts the correct result, while the other fails in either one or the other.

Another instructive and interesting experiment is shown in Fig. 9. Here one of the return wires to the source is placed as close as possible to the mercury trough, thus making the part *abc* of the circuit practically non-inductive. The motion will then be as shown, which at first sight would appear to be a shortening of the mercury part of the circuit; but the non-inductive part *abc* is now no longer a part of the circuit, as far as the encircling magnetism is concerned, because magnetically its effect is zero. Hence a movement from *c* to *b* really lengthens the circuit by the amount *cb*, but this time in the return part of the circuit. After this movement there is as much more flux surrounding the wire as corresponds to that increase of effective length *cb*, that is, to the decrease of the ineffective or non-inductive length.

This experiment also shows that the increase of length takes place equally well in a solid as in a liquid conductor, hence is not due to any movement of the liquid.

As the direction of motion of the bridge wire is reversed in Figs. 8 and 9 by merely bringing the return wire nearer to the trough, it necessarily follows that the return wires when very close, have some effect and that there must be some position of the return wire at which there is no further tendency to move. At this point the tendency to lengthen is exactly balanced by an equal and opposite magnetic force elsewhere in the circuit and produced by the motion of the bridge. Thus in Fig. 10 the bridge *B* would move as shown until the tendency to lengthen the curved part of the circuit is balanced by the tendency of the angular part to straighten (as shown in Fig. 3) by the same magnetic forces as those which tend to stretch the wire. In this position the magnetic energy of the whole circuit is greatest; the inductance

FIG. 10. FIG. 11. FIG. 12. FIG. 13.



would be decreased by a motion of the bridge arm in either direction, hence is the greatest that can be produced by moving that arm. The tendency to increase in length is then equal to the tendency of that angle to straighten out.

Another such instance is that of a bifilar non-inductive circuit, in which there should be no stretching because by doing so there would not be produced any additional flux. In a non-inductive part of a circuit the two currents are equal and opposite, hence there is no effective current, and therefore in that sense it is not a real and effective circuit.

In the following modifications of Ampere's classic trough experiment the same results are shown. The ordinary arrangement was shown in Fig. 4. When the leads are brought around to the other side, as shown in Fig. 11, the motion will be in the same direction as before, thereby diminishing the area of the circuit, contrary to some teaching. By bringing the return wires

very close to the troughs, as shown in Fig. 12, the direction of motion is reversed.

A mechanical device with sliding contacts instead of mercury troughs might be devised so as to give continuous rotary motion by this stretching of the conductors, thus producing a self-starting alternating current motor; but the large currents necessary to produce strong forces give rise to difficulties at the rapidly moving sliding contacts. Such a motor would have the characteristics of a low volt machine like those of the unipolar type. Industrial applications of this force might, however, be possible in some electric furnaces in which large currents pass through liquid conductors, and in which such a force might be used to produce internal circulation; in liquids, small forces (like differences in densities, for instance) can be used to produce very decided motions.

One of the curious consequences is that if this stretching force were large enough a wire should wind itself into a coil, as shown in Fig. 13, and thereby develop a counter e.m.f.; or conversely, unwinding such a current carrying coil should generate more current.

SUMMARY.—The above is believed to show: that there were reasons to expect that a current develops an axial force in its conductor which tends to straighten and stretch it; that experiments show the existence of such a force, and that it can be made to produce bodily motion; that while it may be possible to explain most of the various different motions by the numerous different older laws which must be learned by the student, this one simple law explains them all, thus making the learning of most of the numerous older laws unnecessary; that the reason for the existence of such a force would be readily conceived by the student, thereby avoiding the necessity of a parrot-like memorizing of the older laws; that some of the experimental results show that former teachings were wrong in at least one respect; that this stretching force enables the correct results to be predicted in all known cases while one of our older laws predicts wrong results; that some of the observations or deductions (as, for instance, *b*, *e*, and *f*) cannot, it seems, be explained or are not suggested by the older laws; that for the mathematical physicist the older laws seem to suffice, but for the student and practising engineer the conception of such a stretching force simplifies the

understanding of some of the actions of currents with which he may have to deal; and that the existence of such a stretching force may suggest ideas or explain phenomena which the older laws would not.

The following conclusions seem to be true, although still subject in part to positive and quantitative demonstration:

In a conductor free from all external influences a current exerts a stretching force, due to its magnetic effect, which is independent of the direction of the current or of the length of the conductor and is presumably proportional to the square of the current and inversely proportional to the cross section; it continues to act, no matter to what length the conductor has been stretched by it, and is therefore not of the nature of a strain; it is affected by neighboring currents and becomes less as these neighboring currents neutralize the magnetic effect of the current, being zero in a perfectly non-inductive circuit; when it produces motion a counter e.m.f. is produced; when such motion is reversed by a stronger opposing mechanical force, a direct e.m.f. is produced.

Standard Cement Specification. (*Eng. Record,* lxii, 14.)—The British Standard Specification for Portland Cement has been revised a second time by the Engineering Standards Committee, as a result of the investigations of the sectional committee on cement. For determining initial set the Vicat needle alone is specified, and the British Standard set aside. Clauses are inserted regarding minimum lime content and total loss on ignition and a provision for limiting the total amount of sulphur present whether as sulphates or sulphides. The instructions for gauging have been modified so as to remove any ambiguity as to the actual consistency of the cement. The increase in tensile strength of cement and sand briquettes is now graded in a similar manner to that of neat cement briquettes.

Testing Boiler Feed Water Electrically. W. POLLARD DIGBY. (*Jour. Inst. Elec. Eng.,* Aug., 1910.)—This test is based on the fact that pure water is an imperfect electrical conductor, but if small quantities of salts are dissolved in it the conductivity is greatly increased, in proportion to the quantity of salts. Hence by passing a current through a tube of definite dimensions with platinum electrodes, and reading the resistance by an ohm-meter, the conductivity is a measure of the total salts in solution.

Rotating Graphite Anode. J. W. TURRENTINE. (*J. Ind. Eng. Chem.*, ii, 342.)—The author has designed a satisfactory graphite anode for use with the graphite cathode dish. It is in the form of a dish, 4 cm. deep with walls 2 to 3 mm. thick, cylindrical for 2 cm. of its depth and then a truncated cone narrowing from 8 to 3 cm. In the bottom is a hole 1.2 cm. in diameter and four equidistant radial slits in the sloping portion of the side. It is supported for rotation by the outward pressure on its inner wall of three aluminum prongs attached to the rotating shaft. Rotation brings the bulk of the solution between the cathode dish and the outer walls of the anode. In such electrolyses the anodic oxygen does not pass over and tend to oxidize the metal on the cathode. The porosity of the graphite is greatly reduced, without notably impairing the conductivity, by treatment with paraffin or ceresin, while the tendency to flake is not conspicuous except at fairly high current densities, such as 6 ampères per square d.c.m.

Electric Steel Refining. D. F. CAMPBELL. (*Iron Age*, lxxxvi, 15.)—In the electric furnace almost any degree of refining can be economically effected and the removal of sulphur, phosphorus and oxygen is especially easy. This is probably due to at least three causes:

1. The intense heating of the slag, which is the place where refining occurs, owing to the high temperature and the extreme fluidity of the slag, the rate of the reaction is very great, because the velocity of the reaction rises very quickly for high temperatures, and not in direct proportion to the temperature.

2. The extremely basic slag that can be kept in a very fluid state, and the calcium carbide formed by the action of the arc on the calcareous slag, are especially advantageous for de-sulphurization.

3. The violent motion of the steel, resulting from the convection currents produced in the bath, due to the two intensely hot areas caused by the arcs below the electrodes, increases the volume of steel exposed to the hot and fluid slag area—hence the rate of refining.

Ferrotitanium in Steel and Iron Castings. LEONHARD TREUHEIT. (*Iron Age*, lxxxvi, 12.)—Mr. Treuheit, superintendent of the Yaeger Iron and Steel Works of Elberfeld, Germany, controverts the statements of firms selling ferrotitanium and similar alloys on the following points, based on factory experience: 1. That ferrotitanium alloys do *not* raise the temperature as claimed. 2. The fracture photographs show that the claim that these alloys produce a finer structure is incorrect. 3. That they do *not* reduce sulphur. 4. That the use of these alloys is not economical in comparison with other purifiers, such as, for instance, aluminum.

THE INFLUENCE OF CHEMICAL AFFINITY IN CERTAIN PHENOMENA CALLED ADSORPTION.

BY

M. LÉO VIGNON.

(Translated from *Comptes rendus*, cli, No. 16, by W. J. Williams, F.I.C.)

If a solid surface be in contact with a heterogeneous fluid-medium, either liquid or gaseous (a solution or a mixture of solids, of liquids, of gases, or of vapors) adsorption takes place, and can be measured by the changes of composition to which the liquid or gaseous medium is subjected under the influence of this solid surface.

It has long been known that in all substances a force is manifested between the particles, which has been called *molecular attraction*, on account of the special meaning which chemists give to the word *molecule*. This attraction, quite distinct from universal attraction, is characterized by the fact that it is exerted between certain particles, and only at very small distances, comprised in an extremely limited field. It may be added that this particular attraction causes the phenomena of cohesion, adhesion, friction, capillarity, viscosity, and surface tension, that it is very strong in solids, weaker in liquids and almost negligible in gases.

In the study of the phenomena of adsorption, it is evidently necessary to recognize the physical condition of the body under consideration, and in particular to determine if the substances mixed with the fluids are *actually* dissolved. In fact, if the solid surface is in contact with a liquid in the conditon of a false solution, or with a gas holding a liquid or a solid in suspension, the undissolved solid or liquid particles will attach themselves to the solid surface by the mere effect of this particular attraction.

I have given examples of this order of phenomena in showing that sand and asbestos fix the coloring matters in a colloidal solution ("Adsorption of Certain Coloring Matters," *Comptes rendus*, July 4, 1910).

These experiments were carried out by taking river sand and asbestos as the solid surfaces, that is to say, substances almost inert from the chemical point of view.

I have sought to determine whether the *chemical nature* of the solid surface had any influence on the phenomena of adsorption.

With this end in view, for chemically inert solid surfaces I substituted chemically active solid surfaces, notwithstanding their insolubility, the chemical activity of these surfaces being deduced from their chemical composition.

I have the honor of presenting the results thus obtained to the Academy of Science.

The solid surfaces employed, chosen for their chemical activity, were silica, alumina, zinc oxide, silk, and asbestos (as a standard).

On these surfaces, well washed with distilled water, there were permitted to react aqueous solutions containing one one-thousandth of coloring matter *actually dissolved* (picric acid, fuchsine S, see *Comptes rendus,* July 4 1910).

Two series of experiments were made, the first by filtration, the second, by prolonged contact.

1. *Filtration.*—Twenty-five c.c. of the colored solution were passed at the ordinary temperature over a cylindrical column, 0.01 m. in diameter and 0.20 m. high, of the adsorbing matter in powder or in filaments. I determined the coloring matter in the liquid drained off.

FIXATION OF THE COLORING MATTER, IN 1/1000 AQUEOUS SOLUTION, PER 100 PARTS OF ADSORBENT MATTER.

ADSORBENT MATTER.	PICRIC ACID.	FUCHSIN S.
Calcined silica	0.00	0.00
Hydrated silica	0.00	0.21
Hydrated alumina	1.10	1.18

By this method the period of contact was very short (1 to 2 minutes). I then passed on to experiments of longer duration.

2. *Prolonged Contact.*—One Gm. to 2 Gm. of the solid substance, in powder boxes of 250 c.c. capacity closed by emery stoppers, were placed in contact with 200 c.c. of a one-thousandth aqueous solution of fuchsine S, acidulated with 5 parts per 1000 of H_2SO_4. Contact was renewed by agitation every 30 minutes. the amount of adsorption was estimated at the end of 2, 3, and 4 days, the mixture being kept at ordinary temperature.

ADSORPTION OF FUCHSIN S IN AN AQUEOUS SOLUTION OF 1 PER 1000, PER 100 PARTS OF ADSORBENT MATTER.

ADSORBENT MATTER.	AFTER 2 DAYS.	AFTER 3 DAYS.	AFTER 4 DAYS.
Asbestos, 2 Gm.	0.03	0.11	0.11
Zinc oxide, 1 Gm.	3.84	5.45	5.45
Hydrated silica, 1 Gm.	0.06	0.06	0.06
Hydrated alumina, 1 Gm. ..	4.02	4.02	4.02
Calcined silica, 1 Gm.	0.06	0.06	0.06
Scoured silk, 0.99 Gm.	6.26	7.91	7.91

These results are plainly significant; the almost chemically inert substances (asbestos) did not fix, so to speak, coloring matters actually dissolved; it was the same with silica. Alumina, zinc oxide, and silk, on the contrary, show a notable adsorption, when the period (duration) of contact is sufficiently long.

To summarize: Insoluble solid matter, but with definite chemical functions, will or will not fix actually dissolved coloring matter, according to the chemical functions they possess.

These results agree with those of Briggs (*Journal of Phys. Chem.*, 1905, ix, 617). Thus quartz, an insoluble and acid body, adsorbs alkaline hydrates and carbonates; while sodium, magnesium and ammonium chlorides do not undergo adsorption.

It must, then, be admitted that chemical affinity is the force which determines on certain surfaces, the fixation of certain substances actually dissolved in fluids (liquid or gaseous) and in contact with these surfaces.

In this way the phenomena may be explained as shown by Briggs with quartz and by myself with alumina, silica, zinc oxide and different textiles.

The phenomenon, called adsorption, in a word, includes two quite distinct cases; bodies in false solution or in suspension are fixed by this particular attraction; those which are actually dissolved, obey the laws of chemical affinity.

It may be observed, further, that most bodies exercise a chemical action upon each other at the ordinary temperature; this is very marked in non-saturated compounds, such as carbon monoxide; but in the saturated compounds this chemical action may be very weak, scarcely perceptible, but seldom absent. It is obvious that the different atomicities which are saturated are not equal quantitatively; in a saturated compound there generally

remains a residue of activity capable of showing itself in a certain sense. The existence of numerous molecular combinations, and the fixation of water by cell-bodies in contact with the atmosphere, appear to demonstrate the existence of this activity.

Segregation in Soft Steel Ingots. G. B. W. (*Iron Age*, lxxxvi, 13: From a paper by Prof. Wust and Herr Felser in *Metallurgie* for June 22, 1910.)—This article is well illustrated and goes into detail as to the influence the segregation in soft steel has on the mechanical properties of round bars rolled from the ingots. The amount and distribution of the segregation is shown by analyses.

Sulphur and phosphorus segregate the most, carbon, manganese and copper in a lesser degree. Sulphur shows more segregation in large ingots; phosphorus, carbon and manganese show the reverse. The influence of segregation is not considerable on the tensile tests, but it affects the ductility. The greatest effect is visible in the shock tests, the segregated material being very unreliable and brittle.

Strength of Chains. (*Amer. Mach.*, xxxiii, 37.)—A convenient and reasonably accurate rule for estimating the safe working strength of a chain is: Express the diameter of the wire or bar of which the links are made in 16ths of an inch. Square this number and multiply it by 80, gives the safe working load in pounds. Thus for a chain made of ½ inch. wire:

$$8 \times 8 = 64 \times 80 = 5120 \text{ lbs., safe working load.}$$

The proof test of ½ inch chain is 7500 lbs., approximately 50 per cent. over safe working load.

Cassava and Other Succulent Vegetables. C. C. MOORE, WASHINGTON, U. S. A.—Mr. Moore has patented a process for manufacturing starch from these vegetables. The finely comminuted cassava is sprinkled with a solution of sulphurous acid or of a sulphite, such as calcium bisulphite, preferably in the proportion of 10 lbs. of calcium bisulphite per ton of material, and then dried. This prevents or restrains deleterious changes due to enzyme actions and thus preserves the full content of starch and sugars in the cassava, and also converts the less dense starch granules into a denser form and thus increases the yield of marketable starch. The dried product is worked up by the usual methods, and the separated starch liquor is utilized for the production of sugars or alcohol.

THE APPLICATION OF THE ARCHIMEDEAN PRINCIPLE TO THE EXACT DETERMINATION OF GASEOUS DENSITIES.

BY

MESSRS. A. JAQUEROD and M. TOURPAIAN.

(Translated from *Comptes rendus*, cli, No. 16, by W. J. Williams, F.I.C.)

THE hydrostatic method has not been used hitherto, at least for exact measurements, for the determination of the density of gases. We will describe in this article an apparatus of great precision based on the principle of Archimedes, and which avoids several inconveniences inherent to the methods generally used.

A cylindrical glass float, about 200 c.c. in volume, calibrated exactly, is suspended vertically, by a platinum wire, from the beam of a balance and balanced by a suitable counterpoise; the float is enclosed in a glass tube of slightly larger size, in which it can swing freely; at the top this tube ends in a capillary tube through which the platinum wire passes, and the gas is admitted by means of a second capillary tube fused to the lower end. The whole is kept at a constant temperature by means of a water bath, in which an accurate thermometer is immersed and it is provided with a stirrer.

The carefully purified and dried gas, is introduced into the apparatus at a speed of about 1 litre per hour; little by little it displaces the air, and the weighings may be begun some hours after starting the flow of gas, and can be repeated continuously as long as the gaseous flow lasts.

At the moment of weighing the current of gas is interrupted, the diffusion of the external air takes place very slowly on account of the apparatus used, and the equilibrium position of the balance is determined by the ordinary method of oscillations. Barometer is read simultaneously with temperature of the bath.

To calculate the pressure exerted on the float by a given gas, and from that the density of the gas, it is first necessary to know the tare, *i.e.*, the weight of the float, in a vacuum. As it is impossible to weigh it directly in a vacuum, this determination is made by the aid of two gases, oxygen and hydrogen,

whose density, or rather the mass of one litre under normal conditions is known exactly. We have thus obtained, as will be seen later, two series of very concordant measurements.

When working with a gas denser than air, oxygen for example, the interruption of the flow can be made without inconvenience during a time sufficient to observe the equilibrium position of the balance. In the case of hydrogen, on the other hand, it is no longer so, and immediately the gas stops, a progressive increase of the pressure is set up, due to the external air replacing hydrogen. We were then compelled to weigh without interrupting the flow of gas, and from that time the constancy remained perfect. A correction is necessary on account of the dynamic effect, which is actually very slight. We obtained this by the following method:

The hydrogen was prepared electrolytically, in such a way that an ampere meter placed in the electric circuit gave, in a relative measure, the exact flow of gas. Weighings were made with decreasing intensities and the values extrapolated to an intensity of zero, corresponding to the complete stoppage of the gas. Thanks to the smallness of the correction,—besides this function is almost linear to the current,—this device gave very satisfactory results.

The oxygen and hydrogen used in these researches were prepared by the electrolysis of a solution of potassium hydroxide and purified by passing through a tube heated to 350° C., containing platinized asbestos, then dried over sulphuric acid and phosphorus pentoxide.

Here is a summary of the results obtained. The numbers below represent the tare of the float in a vacuum; each is the mean of a large number of weighings. In this series the temperature varied from 15° to 16° C., and the barometric pressure between 715 mm. and 725 mm.

THE TARE DETERMINED BY MEANS OF:

OXYGEN.			HYDROGEN.
0.18260	0.18267	0.18265	0.18263 Gm.
0.18268	0.18255	0.18265	0.18264 Gm.
0.18266	0.18257	0.18258	0.18263 Gm.
0.18265	0.18264	0.18260	0.18268 Gm.
0.18256	0.18263	.....	0.18262 Gm.
Mean (oxygen).....0.18262			Mean.....0.18264 Gm.

The agreement of the individual measurements is better in hydrogen than in oxygen, which is easily explained; in fact the pressure of hydrogen is 16 times weaker, and the errors of temperature and pressure have 16 times less influence than is the case with oxygen.

The advantage of weighing in hydrogen consist in this, that it is almost equivalent to weighing in a vacuum; the pressure of the gas in fact only amounts to hardly 2 cg., and the uncertainty as to the absolute value of the mass of a litre of hydrogen only plays an insignificant rôle.

The determinations, taken as a whole, do not then permit the calculation of the relation of the densities $\frac{O}{H}$, but they give a new confirmation of the value adopted for the mass of the normal litre of oxygen, say 1.4290 Gm., a confirmation which is correct to about one ten-thousandth.

Chemical Action of Ammonium Persulphate. A. SCHULLER. (*Phot. Rundschau,* xxiv, 161.)—The ammonium persulphate penetrates the gelatin and slowly changes the silver to silver sulphate, which is converted into persulphate by the excess of ammonium persulphate. The silver persulphate is much more energetic than the ammonium persulphate and attacks the silver of the image to form silver sulphate, which is converted as before. Thus the active agent in the reduction is silver persulphate, the ammonium salt merely serving to convert the silver sulphate into silver persulphate. The action is slight in the shadows of the negative, not merely because the concentration of the silver persulphate is less there than in the denser parts of the plate, but because silver persulphate hardens the gelatin and can diffuse more rapidly into the mass of liquid where the hardening effect is slight. Hence the action of the persulphate reducer is due to the varying diffusibility of silver persulphate.

The Corrosion of Iron. J. N. FRIEND. (*Engineering,* lxxxviii, 531.)—Only two theories of corrosion merit attention, the acid and the electrolytic theory. Pure iron, oxygen, and water may be in contact an indefinite time without mutual action; the presence of acid is necessary to cause rusting, the acid acting as a catalyzer. Generally CO_2 is the acid present. A very small quantity of CO_2 forms $FeCO_3$ or $FeH_2(CO_3)_2$, which is decomposed and forms rust by the oxygen of the air, setting free CO_2 to begin the cycle again. The various experiments which appear to show that pure water, oxygen, and iron combine to form rust are due to the fact that the water used is not pure.

Pickling Castings and Dips Used. (*Amer. Mach.*, xxxiii, 34.)—Cast-iron is poured at such high temperatures that it is impossible to prevent the adherence of sand and the formation of scale from the combination of iron oxide and sand. This is removed by pickling. The pickle is generally sulphuric acid, sometimes hydrochloric acid. Now foundries are commencing to use hydrofluoric acid which attacks the sand, but only affects the iron very slowly. The usual strength is 1 part of hydrofluoric acid to 10, 15, or 20 parts water, according to conditions. The tanks are made of oak lined with asphaltum, and the dipping baskets of hard rubber, wood fibre or wood, and should have no metal whatever. The speed is hastened by heating the bath to 150° F. by a steam-pipe. A special dip for electro-galvanizing is made by adding to the dilute acid one-half pound of sheet-zinc to each 25 gallons, adding more as it works out.

Bright dip, to bring the work out white:

Hydrofluoric acid	24 oz.,
Nitric acid	10 oz.,
Metallic zinc	2 oz.,
Water	2 gallons.

Satin finish dip:

Hydrofluoric acid	1 part,
Water	3 parts,

then dried and run through the bright dip.

Bright dip for copper, brass, bronze, or German silver:

Hydrofluoric acid	4 quarts,
Nitric acid	3 quarts,
Common salt	small handful.

Another satin dip is:

Hydrofluoric acid	2 parts,
Nitric acid	1 part,
Hydrochloric acid	½ part,
Water	5 parts,

then rinse, dry, and run through the bright dip. Or

Hydrofluoric acid	2 parts,
Nitric acid	1 part,
Water	10 parts.

Cementation of Iron by Solid Carbon. G. CHARPY AND S. BONNEROT. (*Comptes rendus*, cl, 173.)—Cementation of a soft open-hearth steel in a tube by means of solid carbon was attempted. The tube was exhausted by a mercury pump. There was no absorption of carbon. Endeavors will be made to determine if carbon once absorbed will diffuse under such treatment.

FRANKLIN INSTITUTE.

AWARD OF THE ELLIOTT CRESSON MEDAL TO DISTINGUISHED SCIENTISTS.

Ever since its foundation, one of the most important branches of the Institute's work has been the examination of new inventions for the guidance and encouragement of inventors, conducted by its Committee on Science and The Arts, on whose recommendation the Institute bestows awards for inventions or discoveries of signal merit. Without any formal measures the spirit in which the work of this committee is conducted has broadened, in keeping with the march of progress and advance of scientific knowledge, to the consideration of the basic advances and their general value in adding to material progress rather than the recognition of specific variations and new forms of appliances or materials already known.

There is a handful of men distributed over the four quarters of the civilized world whose first thought and labors are devoted to the solution of the problems of pure and applied science. Their work is seldom of a character that is embodied or can be represented by material results. Their achievements clear the way for the lesser task of specific application by others to whom generally come the credit and the reward. It is, therefore, consistent with the aims of the Institute and fitting to the already tacitly established functions of the Committee to recognize obvious additions that such men have made to the fund of human knowledge. Accordingly at the meeting of 5th October, 1910, the principle was formally adopted of recognizing the life-work of scientists and technologists of long established reputation by according to such scientists and technologists the highest awards of the Institute. By unanimous adoption the resolution was made to award for distinguished, leading and directive work in their respective fields the following named eminent scientists and technologists:

SIR JOSEPH J. THOMSON, DR. JOHN A. BRASHEAR,
PROF. ERNEST RUTHERFORD, MR. JOHN FRITZ,
SIR ROBERT A. HADFIELD, DR. EDWARD WESTON,
DR. HARVEY H. WILEY.

SIR JOSEPH JOHN THOMSON, M.A., D.Sc., LL.D., F.R.S., CAVENDISH PROFESSOR OF EXPERIMENTAL PHYSICS, CAMBRIDGE UNIVERSITY, ENGLAND.

Sir Joseph J. Thomson was born in England in 1856. He was graduated from Trinity College as Second Wrangler, became a Fellow in the college in 1880 and a lecturer in 1883.

Both as an investigator and as a writer he has made an enduring name for himself. Among his published works are "A Treatise on the Motion of Vortex Rings," 1884, "The Application of Dynamics to Physics and Chemistry," 1886, "Recent Researches in Electricity and Magnetism," 1895, "Discharge of Electricity through Gases," 1903. As may well be

supposed, Sir. J. J. Thomson, who is in the prime of life, is a frequent contributor to scientific journals. The investigations which resulted in his lectures on "Electricity and Matter" delivered at Yale University have been continued and one needs to be a persistent reader of the *Philosophical Magazine, Nature,* and other scientific publications to keep in touch with the investigations he is now making. Not the least of his important work has been that of establishing at Cambridge of a School for Physical Research that has become known throughout the scientific world. This school has become known not only through the character of the research work done in it, but through the men who have gone out from it and are now leading in the scientific thought and teaching of the day.

ERNEST RUTHERFORD, F.R.S., M.A., D.Sc., LL.D., PROFESSOR OF PHYSICS, OWENS COLLEGE, VICTORIA UNIVERSITY, MANCHESTER, ENGLAND.

Professor Ernest Rutherford was born in New Zealand in 1871. There he received his preliminary education. He then went to England and in 1893 was graduated from Cambridge University with first-class honors in Mathematics and Physics. He received the degree of D.Sc. from Trinity College, N. Z., in 1901 and in 1904 delivered the Bakerian lecture before the Royal Society. In 1898 he was appointed Macdonald Professor of Physics in McGill University, a position which he filled until 1907. It was while at McGill University that he published "Radio-Activity" and "Radio-Active Transformation." This latter book was the final form given to the third course of Silliman Memorial Lectures which he delivered at Yale University in 1905.

The work of Professor Rutherford in the investigations of radio-activity has made the entire scientific world his debtor.

SIR ROBERT A. HADFIELD, D.Sc., LL.D.

Sir Robert A. Hadfield was born in Sheffield in 1859. He was educated at the Collegiate School and received unusual parental encouragement in pursuing his natural scientific bent. At the age of fifteen he went into the laboratory at his father's works at Attercliffe intending to specialize in that department. After a year or two through the ill health of his father much of the burden of the management of the works devolved upon the son and eventually he assumed entire charge. That position he has continued to hold with remarkable effect upon the fortunes of the firm, the progress of which has been uninterrupted.

As summarizing Sir Robert's contributions to the science of metallurgy, it is of interest to present the following list of some of his best known papers: "Manganese in Its Application to Metallurgy (manganese steel)"; "Some Newly Discovered Properties of Iron and Manganese"; "Manganese Steel"; "Alloys of Iron and Silicon"; "Alloys of Iron and Aluminum"; "Alloys of Iron and Tungsten."

The high esteem in which he is held among scientific men has been frequently attested by the conferment of honors both at home and abroad.

The Hadfield Steel Foundry is an impressive testimonial to the energy and enterprise of a great manufacturer but an incomplete one, for he has in various ways played a notable part in the industrial life of Sheffield.

JOHN A. BRASHEAR, Sc.D., LL.D.

Dr. Brashear was born in Brownsville, Pa., in 1840. During his early career he became identified with the iron industry and for many years held the post of Master Mechanic in rolling mill operations. Early in life he became interested in astronomical pursuits, an interest which he maintained throughout his association with the iron industry and eventually led him to engage in the manufacture of optical and astronomical instruments. The many articles on astronomical subjects which Dr. Brashear contributed to the daily press enlisted the interest and aid of Mr. William Thaw who furnished the means to build and equip a better workshop for the manufacture of optical instruments than was then available. To this unsolicited aid Dr. Brashear attributes much of his early success. In 1881 in association with Mr. James B. McDowell the present plant was organized. Among the instruments he constructed which have secured an epoch making place in scientific investigation may be mentioned the speculum plates for the famous diffraction gratings of Professor Rowland, the optical parts of the equally famous interferometer of Professor Michelson and the bolometer, an instrument capable of measuring incredibly small changes in temperature.

Dr. Brashear was formerly Director of the Allegheny Observatory and Acting Chancellor of the Western University of Pennsylvania. He has been recipient of degrees and honors at home and abroad from a number of colleges and scientific societies.

JOHN FRITZ, ESQ.

Mr. Fritz was born in Chester County in 1822. At the age of sixteen as a blacksmith's apprentice he gained his first acquaintance with the manufacture of iron at a charcoal blast-furnace to which he had been sent to do some repair work. In 1845 he went to Norristown, Pa., and assisted in building what was then considered the best mill in the country for making bar iron. He was soon afterward placed in charge of this mill.

In 1854 he went to Johnstown to direct the rebuilding of the rail mill of the Cambria Iron Company. Here in 1857 he built the first three-high rail mill ever built in the face of strong opposition both of the workmen and of some of the owners of the mill.

In 1860 he became General Superintendent of the newly organized Bethlehem Iron Company, which position he held for over thirty-two years, practically creating a plant which for many years occupied a unique as well as a leading position in the metallurgical industries.

He is honorary member of the Iron and Steel Institute of Great Britain, from which he received the Bessemer Gold Medal for services in the advancement of steel manufacture. He is an honorary member of

the American Society of Civil Engineers and Life Member and Past President of the American Society of Mechanical Engineers. He is also President of the American Institute of Mining Engineers and is an honorary member of the Franklin Institute.

EDWARD WESTON, D.Sc., LL.D.

This distinguished inventor and electrician was born at Brynn Castle near the town of Oswestry, Shropshire, England, on May 9, 1850.

As a boy he was a close student of electricity. His parents desired him to study medicine, but after three years he abandoned his studies and came to America, where after some effort he secured a position with the American Nickel Plating Company. By his efforts both the company's interests prospered and the state of the art was greatly improved.

In the year of 1872 he began exhaustive study and experimental investigation of the dynamo-electric machine. His most active work dates from the time of the formation of a copartnership in the year of 1874 with the firm of Stevens-Roberts and Havell of Newark, New Jersey.

In the fourteen years from 1872 to 1886 Dr. Weston accomplished an extraordinary amount of work on the problems before him and in eleven years three hundred (300) patents on numerous useful applications of electricity had been issued to him.

In 1886 he established the laboratory at Newark where were originated the Weston electrical measuring instruments now used the world over and the equally famous Weston Cadmium Cell and the zero coefficient resistance alloy "Manganin."

The works of the Weston Electrical Instrument Company at Newark, New Jersey, where the Weston products are now manufactured, is the largest and most complete factory of the kind in the world.

Dr. Weston is charter member and Past President of the American Institute of Electrical Engineers. He is Trustee of the Stevens Institute of Technology and an Honorary Member of the Tau Beta Pi Fraternity. He is also member of many other societies here and abroad.

HARVEY W. WILEY, M.A., M.D., PH.D., LL.D.

Aside from Dr. Wiley's well known and valued work in the field of agricultural chemistry, a work which makes all those interested in agriculture, directly or indirectly, his debtors, his aggressive work in minimizing the effects of harmful preservatives in food and drink has commanded the attention not only of the public but of medical societies as well.

Dr. Wiley was born at Kent, Indiana, October 18, 1844. He was graduated from Hanover College in 1867 with the degree of Ph.D. and from Harvard in 1873 with the degree of LL.D. He held the chair of Professor of Chemistry at Purdue University from 1874 to 1883. During the latter part of this period from 1881 to 1883 he served as State Chemist of Indiana. He has also served as delegate to various congresses and occupied other posts of importance.

In 1883 he became chief of the Bureau of Chemistry, United States Department of Agriculture, a position which he has filled with the highest credit to himself and in which he has earned the lasting gratitude of a nation.

PRESENTATION OF ELLIOTT CRESSON MEDAL

TO

JOHN A. BRASHEAR, D.Sc., LL.D., F.R.A.S.

At a special meeting on Friday evening, December 9, 1910, Professor Brashear delivered a lecture on "Contributions of Photography to Our Knowledge of the Stellar Universe."

This meeting was made the occasion for the presentation to him of the Institute's Elliott Cresson Medal for his distinguished contributions to astronomical science. In presenting the medal the President of the Institute, Mr. Walton Clark, said:

"Ladies and gentlemen, members and friends of Franklin Institute,—we have gathered in this historic hall of our venerable Institute, to present to John Alfred Brashear, Doctor of Science, Doctor of Laws, Fellow of the Royal Astronomical Society—eminent and honored as engineer, scientist, astronomer, educator, craftsman and man, the highest honor in our gift—the Elliott Cresson Medal.

"We do this upon the following recommendation of our Science and Arts Committee:

"This Committee recommends that the Elliott Cresson Medal be awarded for 'distinguished leading and directive work in the production and perfection of instruments for astronomical research' to John A. Brashear, Sc.D., LL.D., of Pittsburg, Pa.

"Dr. Brashear, I am honored in being the medium through which The Franklin Institute conveys to you its Elliott Cresson Medal and accompanying certificate."

After expressing his thanks for and appreciation of the honor conferred, Professor Brashear described the methods and apparatus employed in modern astronomical research and the recent important advances in astronomical knowledge, made possible by the applications of photography to this field of work. The lecture was illustrated by a large number of interesting and beautiful photographs of nebulæ, star clusters and other heavenly bodies.

PRESENTATION OF ELLIOTT CRESSON MEDAL

TO

EDWARD WESTON, D.Sc., LL.D.

The Elliott Cresson Medal recently awarded by the Franklin Institute to Dr. Weston for his achievements in Electrical Science was presented to him by the Secretary of the Institute on the evening of December 16, at a dinner given at The Lotos Club, New York City.

In presenting to Dr. Weston the Elliott Cresson Medal Dr. Owens said:

"Dr. Weston, by virtue of authority delegated to me, I present to you on behalf of the Franklin Institute of the State of Pennsylvania, the Institute's Elliott Cresson Medal and accompanying certificate in recognition of your brilliant and successful researches in the field of electrical discovery, and also in recognition of the indomitable energy you have so lavishly and so effectively expended throughout a period of nearly half a century in the advancement of the applications of electricity to fill the needs of and supply the wants of an ever increasingly complicated and exacting civilization.

"Speaking for myself, I think that you know, Dr. Weston, that I deeply appreciate the honor of being even the humble means of transmitting to you this award, and it is due to you, Sir, to say that from no one have I drawn greater inspiration in the past, and certainly no one has lent me such assistance as you have in a twenty-year effort to educate young men in this country and elsewhere to a sound understanding of the principles of science and their application in engineering."

A number of speeches were made by those present, expressive of gratification at the action of the Institute in recognizing the worth of Dr. Weston's work and expressive of the high individual opinion held, not only of Dr. Weston's efforts to advance electrical science, but also of his many personal qualities which have endeared him so greatly to his numerous friends.

Those invited to be present on the occasion included: Dr. Louis Duncan, formerly of The John Hopkins University, Past President American Institute of Electrical Engineers, and Honorary Member of the Franklin Institute; Dr. Francis B. Crocker, Prof. of Electrical Engineering, Columbia University, also Past President of American Institute of Electrical Engineers; Prof. Charles F. Chandler, Emeritus Professor of Chemistry, Columbia University; Prof. Cyrus F. Brackett, Emeritus Professor of Physics, Princeton University; Mr. Gano Dunn, Chief Engineer, Crocker-Wheeler Electric Co.; Mr. L. A. Osborne, Vice-president, Westinghouse Electric & Manufacturing Company; Dr. Charles P. Steinmetz, General Electric Company; Mr. William Stanley; Mr. John J. Carty, Chief Engineer, American Telephone & Telegraph Company; Mr. Charles W. Price of the *Electrical Review;* Mr. W. D. Weaver of the *Electrical World,* Mr. Samuel Insull, President, Chicago Commonwealth Company, Dr. S. W. Stratton, Director, U. S. Bureau of Standards; Colonel Samuel Reber, Signal Corps, U. S. A.; Prof. D. C. Jackson, Massachusetts Institute of Technology, President of the American Institute of Electrical Engineers; Ralph W. Pope, Secretary, American Institute of Electrical Engineers, Honorary Member of The Franklin Institute; Mr. W. C. L. Eglin, The Philadelphia Electric Company; Dr. Alexander C. Humphreys, President, Stevens Institute of Technology.

PRESENTATION OF THE ELLIOTT CRESSON MEDAL

TO

HARVEY W. WILEY, A.M., M.D., PH.D., LL.D., CHIEF CHEMIST, U. S. DEPARTMENT OF AGRICULTURE.

Dr. Wiley kindly consenting to address the Institute at its regular stated meeting December 21, 1910, on "The Applications of Chemistry to Public Welfare," his visit to the Institute was made the occasion for the presentation to him of the Institute's Elliott Cresson Medal and accompanying certificate, for his distinguished services in the field of applied chemistry, by the President of the Institute, Mr. Walton Clark. Mr. Clark read the following resolution of the Committee on Science and The Arts:

"This Committee recommends that the Elliott Cresson Medal be awarded for 'distinguished leading and directive work in the fields of agricultural and physiological chemistry' to Harvey W. Wiley, Esq., M.D., Ph.D., LL.D., Chief Chemist of the Department of Agriculture, Washington, D. C."

Addressing the audience, Mr. Clark said:

"The services of Dr. Wiley in the cause of science and for the good of his fellow citizens and the inhabitants of the world generally are too well known to need any comment, and I will not dwell upon them. Dr. Wiley's record as a scientist is in part covered by the statement which I have in my hand, but even it is so long that I will not detain you by mentioning more than a few of the many honors and recognitions he has received. Dr. Wiley is Professor or Consulting Professor of Chemistry in several of our large universities, is Chief Chemist of the U. S. Department of Agriculture, is President of The American Therapeutic Society, Vice-president of The Society of Chemical Industry, Chairman of The Board of Food and Drug Inspection; has represented the United States in numerous international congresses and expositions, and is a member or honorary member of some thirty to forty national and international scientific associations. His decorations include Chevalier Merite Agricole, Chevalier Legion d' Honneur."

To Dr. Wiley Mr. Clark said:

"The Franklin Institute gratifies and encourages its friends by this evidence that it appreciates work of a high scientific and beneficent character, and that it recognizes in you a natural recipient for the highest honor it has to confer; and I am pleased, indeed, to be associated with the transfer to you of this evidence of the Institute's appreciation of the high merit of your work—the Elliott Cresson Medal and certificate."

FRANKLIN INSTITUTE.

(*Proceedings of the Stated Meeting, held Wednesday, December 21, 1910.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 21, 1910.

PRESIDENT WALTON CLARK *in the Chair.*

The Stated Meeting of the Institute was held this evening at eight o'clock.

Present 175 members and visitors.

Additions to membership since last meeting, 6.

The following nominations were made for officers and managers, to be voted for at the Annual election to be held January 18, 1911:

For *President* (to serve one year), Walton Clark.

For *Vice-President* (to serve three years), James Christie.

For *Treasurer* (to serve one year), Cyrus Borgner.

For *Managers* (to serve three years), John Birkinbine, Walton Forstall, Dr. E. Goldsmith, Louis E. Levy, Richard Waln Meirs, Coleman Sellers, Alba B. Johnson, A. P. Robinson.

For *Managers* (to serve one year), Prof. G. A. Hoadley, G. E. Kirkpatrick, Dr. Isaac Norris, Jr.

After the nominations for officers Dr. Harvey W. Wiley, Chief of the Bureau of Chemistry of the U. S. Department of Agriculture, was presented the Institute's Elliott Cresson Medal and accompanying certificate, in recognition of his distinguished leading and directive work in agricultural and physiological chemistry, by President Walton Clark, whose remarks on the occasion appear elsewhere in this issue of the JOURNAL.

Dr. Wiley was then introduced and delivered a most interesting and instructive address on the "Applications of Chemistry to Public Welfare."

After the address a unanimous vote of thanks was extended Dr. Wiley and his address referred to the Committee on Publication.

Mr. Henry A. Gardner, Director of the Scientific Section of the National Paint Manufacturers' Association, and to be after January the Assistant Director of the Institute of Industrial Research, Washington, then presented an interesting communication on the technology of pigments and their applications. The speaker described the various processes in the manufacture of paints and presented results of numerous tests made in various parts of the country on wood and metal structures. The paper was illustrated by one hundred and fifty lantern slides.

After a brief discussion a vote of thanks was tendered Mr. Gardner.

Adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, December 7, 1910.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 7, 1910.

MR. THOMAS SPENCER *in the Chair.*

The following reports were presented for final action:

No. 2426.—Welin's Life Saving Appliances on Board Ships (Scott Medal). Adopted.

No. 2503.—Bennet Typewriter (Longstreth Medal). Adopted.

The following reports were presented for first reading:

No. 2474.—Baylis' Brush Holder (Certificate of Merit).

No. 2475.—Roper Safety Propeller (Certificate of Merit).

No. 2485.—Gardner Dalite Lamp (Advisory). Adopted.

No. 2489.—Hopkins' Speedometer and Dynamometer (Longstreth Medal).

R. B. OWENS,
Secretary.

SECTIONS.

Mining and Metallurgical Section.—A meeting of the Section was held on Thursday evening, December 1, at eight o'clock.

Mr. Thomas Spencer, temporary Chairman. Present, sixty members and visitors.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Dr. Joseph W. Richards, of Lehigh University, Bethlehem, Penna., who delivered an address on "A Vacation Trip in Scandinavia with some Observations on the Electrometallurgy of Iron and Steel."

The speaker gave an interesting account of a journey through Norway and Sweden which he made during the past summer and described the various iron and steel plants of the countries. He spoke of the utilization of the streams and water-falls for power purposes and presented statistics on the cost of water power in various localities.

Numerous lantern views of Scandinavian scenery, hydro-electric plants and electric furnaces were shown during the course of the lecture.

After a brief discussion the thanks of the meeting were extended to Dr. Richards.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

Section of Photography and Microscopy.—Regular meeting of the Section was held in the Lecture Room of the Institute on Thursday evening, Decem-

ber 8, at eight o'clock., Dr. Henry Leffmann in the Chair, J. W. Ridpath, Secretary. Fifty members and visitors were present.

The minutes of the previous meeting were approved as recorded and noted in the JOURNAL OF THE INSTITUTE.

Mr. W. N. Jennings, of Philadelphia, exhibited a new Aero Camero of the fixed focus type, fitted with a rapid lens capable of covering sharply an 8 x 10 plate, also a multi-speed shutter sufficiently rapid to take a sharp picture from the basket of a rapidly moving balloon. The superior capabilities of this new Aero Camera were illustrated by about fifty slides, taken with a long focus camera, a Kodak, and the new Aero Camera; clearly showing the superiority of the latter in convenience and speed. It is small, light, requires no focussing, and gives sharp pictures at distances varying from a few feet to a mile or more. A flock of sea gulls on the wing taken from a rapidly moving steamer, a bird's-eye view of Philadelphia, and other difficult subjects showed this feature clearly.

Dr. Leffmann showed twelve interesting landscape views; also twenty-eight Swiss and German scenes taken by Mr. Richard Pertuch. These views were all interesting and some were quite beautiful.

No further business appearing, the meeting adjourned at 9.20 o'clock P.M.

J. W. RIDPATH,
Secretary.

Mechanical and Engineering Section.—A meeting of the Section was held on Thursday evening, December 15, at eight o'clock. Dr. George A. Hoadley, temporary Chairman.

After the reading and approval of the minutes of the previous meeting the Chairman introduced Dr. S. W. Stratton, Director of the Bureau of Standards, Washington, D. C., who presented an interesting communication on "The Work of the Bureau of Standards in Connection with Structural Materials." The speaker gave an account of the purposes of the Bureau and the work done by each of its departments. Numerous problems which were presented to the Bureau for solution from time to time were described. Lantern slides of testing apparatus and related subjects were shown during the course of the lecture.

In the discussion which followed Dr. Goldsmith, Messrs. Trautwine, Hering, Cullen, Snook and others participated.

The paper was referred to the Committee on Publications and the thanks of the meeting were extended to the speaker.

Adjourned.

ALFRED RIGLING,
Acting Secretary.

SOME PRACTICAL OBSERVATIONS IN ALASKA.

A lecture bearing the above title was delivered in the Hall of the Institute on Friday evening, December 16, 1910, by Mr. Edward R. Taylor, of Penn Yan, N. Y.

The speaker gave an account of a journey which he made to Alaska during the summer of 1910. He described the conditions existing in that country at the present time and referred especially to the agricultural possibilities, the coal and other mines and their development, and the railroads recently constructed. Views of the Taku glacier, the White-horse Pass, Lake Bennett and other impressive scenery were shown. A detailed description was given of placer mining by the individual as well as on a large scale with streams of water under high head. The lantern slides were made from negatives taken by the speaker during his visit.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. EDW. O. WARNER, Railroad Supplies, Franklin Bank Building, Philadelphia.

MR. N. SPENCER GREENFIELD, 1962 N. Stanley Street, Philadelphia.

NON-RESIDENT.

MR. FRITZ V. BRIESEN, Lawyer, 25 Broad St., New York City.

MR. WM. T. CUTTER, State Chemist, B 4418, New London, Conn.

MR. ELIJAH B. BENHAM, Mechanical Engineer, 6 Central Ave., New London, Conn.

ASSOCIATE.

MR. JOSEPH E. GIBBONS, Student, 1528 Glenwood Ave., Philadelphia.

Changes of Address.

MR. MARK B. REEVES, Wildwood, N. J.

MR. J. B. RUMBOUGH, No. 4 The Iowa, Thirteenth and O Sts., Washington, D. C.

MR. R. A. WIDDICOMBE, 5552 Lakewood Ave., Chicago, Ill.

MR. E. F. MASON, Union Station, Pittsburg, Pa.

MR. JOHN P. EATON, 6114 Spruce St., Philadelphia.

MR. J. SNOWDEN BELL, Singer Building, New York.

MR. J. ALLEN HEANY, Heany Electric Co., Flint, Mich.

M. DE TEIVE E. ARGOLLO, C. E., Hotel Royal, Vienna, Austria.

NECROLOGY.

RESIDENT.

Samuel B. Cawley, 1443 North Thirteenth St., Philadelphia.

Henry Reeves (Stacy Reeves & Sons, 1609–11 Filbert St.), Phila.

Craig D. Ritchie, 414 N. Thirty-fourth St., formerly president of the Real

Estate Title & Trust Company, died on December 10, in his eighty-first year. Mr. Ritchie was considered one of the best authorities in the city on the valuation of real estate, and had frequently been called on by the State and city to give expert testimony. He entered the real estate business when he was 17 years old, was foremost in the organization of the Fremont Club, and was a member of the Penn Art Club, the Pennsylvania Historical Society, and the St. Andrew's Society.

LIBRARY NOTES.

Purchases.

OBERG, ERIK.—Handbook of Small Tools.
STILLMAN, T. B.—Engineering Chemistry (4th ed.).
MOYER, J. A.—The Steam Turbine.
California State Earthquake Investigation Commission, Report (1908–1910).
ALLEN, A. H.—Commercial Organic Analysis, vol. ii (4th ed.).
HOUGH, R. B.—American Woods (vol. xi).
Readers' Guide to Periodical Literature, vol. ii (1905–1910).
Jahrbuch für photographie und reproduktionstechnik (Eder), 1910.
National Association of Cement Users, Proceedings, vol. vi.
CATTELL, J. McK., ed.—American Men of Science.
International Catalogue of Scientific Literature, eighth issue (H. Geology).
HOYER, E. V. and F. Kreuter.—Technologisches Wörterbuch.
Mineral Industry, 1908.
TODHUNTER, I., and PEARSON, K.—History of the Theory of Elasticity and Strength of Materials.

Gifts.

Observatoire de Zi-Ka-Wei. Bulletin des Observations de 1907, fascicule A, tome 33. Shanghai, 1907. (From the Observatory.)
American Climatological Association. Transactions vol. xxvi. Phila., 1910. (From the Association.)
Illinois Bureau of Labor Statistics. Report on the Cherry Mine Disaster. Springfield, 1910. (From the Bureau.)
American Steel & Wire Company. Catalogue and Handbook of Electrical Wires and Cables. New York, 1910. (From the Company.)
Illinois Bureau of Labor Statistics, Third Report on Industrial Accidents in Illinois. Springfield, 1910. (From the Bureau.)
Illinois Bureau of Labor Statistics, Eleventh Annual Report. Illinois Free Employment Offices. Springfield, 1910. (From the Bureau.)
HERING, CARL.—Reprints of Papers. Philadelphia, 1910. (From the Author.)
CASSON, HERBERT N.—The History of the Telephone. Chicago, 1910. (From the Author.)

Minneapolis, Minn., Annual Report of the Water Works Department for year ending December 31, 1909. Minneapolis, 1910. (From the Department.)

Ontario Department of Agriculture. Report of Fruit Branch for 1909. Toronto, 1910. (From the Department.)

Western Australia Statistical Register for 1908. Perth, 1910. (From the Government Statistician.)

Australasian Association for the Advancement of Science. Report of the Twelfth Meeting held at Brisbane, 1909. Brisbane, 1910. (From the Association.)

Cornell University Register for 1906–7 to 1909–10. Ithaca, 1910. (From the University.)

Chicago, Rock Island & Pacific Railway Company. Thirtieth Annual Report, June 30, 1910. Chicago, 1910. (From the Company.)

Kapillaranalyse beruhend auf Kapillaritäts und Adsorptionserscheinungen Von Friedrich Goppelsroeder. Dresden, 1910. (From the Author.)

Pennsylvania Museum and School of Industrial Art. Thirty-fourth Annual Report. Philadelphia, 1910. (From the Museum.)

Labour Department (United Kingdom) Report on Collective Agreements between Employers and Workpeople in the United Kingdom. London, 1910. (From the Department.)

Pittsburg Carnegie Free Library. Eighteenth to Twentieth Annual Reports of the Librarian, Pittsburg, n.d. (From the Library.)

St. John, N. B., City Engineer Annual Report, 1909. St. John, 1910. (From the City Engineer.)

Chicago, Burlington & Quincy R. R. Fifty-sixth Annual Report. Chicago, 1910. (From the Company.)

Japanese Imperial Mint, Osaka. Report of the Director for the year ending March 31, 1910. Tokyo, 1910. (From the Director.)

North of England Institute of Mining and Mechanical Engineers' Annual Report of the Council for the year 1909–10. Newcastle-Upon-Tyne, 1910. (From the Institute.)

Connecticut State Geological and Natural History Survey. Bulletin No. 15. Second report on the hymeniales of Connecticut by E. A. White, Hartford, 1910. (From the Survey.)

Royal Academy of Science, Amsterdam. Yearbook for 1909. Amsterdam, 1910. (From the Academy.)

Royal Academy of Science, Amsterdam. Proceedings of the Section of Sciences, vol. xii, Nos. 1 and 2. Amsterdam, 1909 and 1910. (From the Academy.

Tokyo Imperial University. Calendar for 1909–10. Tokyo, n.d. (From the University.)

Canada Agricultural Department. Reports of Experimental Farms, year ending March 31, 1910. Ottawa, 1910. (From the Department.)

Lehigh University, Register of 1909–10. South Bethlehem, Pa., n.d. (From the University.)

Master Car Builders' Association. Proceedings, vol. xliv. Chicago, 1910. (From the Association.)

U. S. Bureau of Construction and Repair. Annual Report of the Chief for 1910. Washington, 1910. (From the Bureau.)

CATLIN, CHARLES A.—Baking Powders. Providence, 1899. (From the Rumford Chemical Works.)

Institution of Civil Engineers. Minutes of the Proceedings, vol. clxxxi. London, 1910. (From the Institution.)

National Electric Light Association. Papers and Proceedings of Convention held at St. Louis, Mo. New York, 1910. (From the Association.)

Iron and Steel Institute, Carnegie Scholarship Memoirs, vol. ii. London, 1910. (From the Institute.)

Philadelphia Bureau of Water. One Hundred and Eighth Annual Report. Philadelphia, 1910. (From the Bureau.)

Canada Department of Trade and Commerce. Report on Canadian Trade, Parts 1 and 3. Ottawa, 1910. (From the Department.)

La Suede Pittoresque. Svenska Turistföreningen. Stockholm, 1910. (From Dr. Joseph W. Richards.)

Bryn Mawr College Calendar. Bryn Mawr, 1910. (From the College.)

BOOK NOTICES.

WIRELESS TELEGRAPH CONSTRUCTION FOR AMATEURS. By Alfred Powell Morgan, Editor Mechanical and Electrical Department of the "Boys' Magazine." Cloth, xii + 188 pages, 7½ x 5½ inches with 147 illustrations. D. Van Nostrand Company, New York, 1910. Price $1.50 net.

Some very interesting exploits in wireless telegraphy by the younger generation have been recently chronicled in the daily press. The enterprise of a boy in his early teens, president of a juvenile wireless telegraph club, testifying in behalf of his fellow operators before a congressional committee is still fresh in the public mind. Such a display of deep interest naturally stimulates a desire to furnish the younger amateurs and the older ones as well with every facility to carry on their experiments to the best advantage. The book is of an exceedingly practical character, consisting essentially of minute directions for the construction of the component parts of the various apparatus comprising the wireless plant, illustrated with well executed dimensioned sketches. The author makes no attempt to consider the principles that enter into the construction described, but he wisely does explain in an introductory chapter by simple physical analogies the train of actions which take place and throughout the subsequent description frequently touches upon, and sometimes at some length, the reasons for the methods adopted. The book will without doubt be welcomed by amateurs and probably by even more ambitious workers.

PHYSICAL MEASUREMENTS. By A. Wilmer Duff, Professor of Physics at the Worcester Polytechnic Institute, and Arthur W. Ewell, Professor of

Physics in the Worcester Polytechnic Institute. Second edition, revised and enlarged with 78 illustrations. Cloth, x + 258 pages, 8½ x 5½ inches. Price, $1.50 net. P. Blakiston's Son & Co., Philadelphia, 1910.

There is always a field for a manual that legitimately lightens the task of the student by distinctly pointing out the objects sought and the best means of overcoming difficulties.

This book contains a limited number of carefully chosen experiments suitable for the laboratory work of students following the usual college course in physics. At the beginning of each topic references are given to a number of well known works and at the end questions on the salient features of the method. The explanations are clear and practical and well illustrated by diagrammatic cuts. The book conforms in size and binding with the well-known work in physics edited by the first-named author, to which it should prove a valuable companion volume.

RECENT ADVANCES IN THE CONSTRUCTION OF ELECTRIC FURNACES FOR THE PRODUCTION OF PIG-IRON, STEEL, AND ZINC. By Eugene Haanel, Ph.D., Director of Mines, Canada Department of Mines, Mines Branch. Bulletin No. 3. Paper, 76 pages 10 x 6½ inches, 13 cuts and 4 inset plates. Government Printing Bureau, Ottawa, 1910.

Since the publication by the Dominion Government in 1904 of its report on electrothermic processes of smelting iron ores and making steel, enormous strides have been made in the application of the electric furnace to metallurgical operations. The present state of the industry is set forth in a comprehensive tabular statement followed by some historical comparisons and technical notes on modern electric furnace practice, particularly that in Norway and Sweden where the absence of coal deposits and abundance of water power constitute a most inviting field for such processes. The account of the Frick induction furnace is of especial interest and promises well for this most recent and increasingly successful method of heating metals.

THE APPLICATIONS OF COLLODION EMULSION TO THREE-COLOUR PHOTOGRAPHY, PROCESS WORK, ISOCHROMATIC PHOTOGRAPHY AND SPECTROGRAPHIC WORK. By Henry O. Klein, F.R.P.S. Cloth, 126 pages, 8½ x 5½ inches, illustrated. Price, 5 shillings, net. A. W. Penrose & Co., Ltd., London, 1910.

In the practice of the three-color process of reproduction in the colors of nature and analagous processes, the employment of suitably orthochromatized plates is a critical feature. Color sensitizing can be accomplished with greater accuracy with collodion emulsion than with gelatine dry plates or the common wet plate, although for black and white line work the latter has never found an equal. It is this circumstance that has given life to the almost extinct process of collodion emulsion.

The book is theoretical and practical and describes at length the sensitizing of plates with dyes for three-color work and methods of testing them;

the making of line half-tone metzograph and tri-color negatives, as well as the production of ferrotypes, photographs on wood, lantern slides, opals, transparencies, etc. Even those who do not use the collodion emulsion process will find much useful information applicable generally to photographic work.

PUBLICATIONS RECEIVED.

The Coke Industry of the United States as Related to the Foundry. By Richard Moldenke. Bulletin 3, Bureau of Mines, Department of the Interior. Washington, Government Printing Office, 1910. 32 pages, 8vo.

Production of Iron and Steel in Canada During the Calendar Year 1909. By John McLeish, B.A., chief of the division of mineral resources and statistics. Ottawa, Government Printing Bureau, 1910. 35 pages, 8vo.

Qualitative Chemical Analysis from the Stand-point of Solubilities, Ionization and Mass Action. By J. I. Hinds, Ph.D., LL.D., Professor of Chemistry University of Nashville and Peabody College for Teachers, Nashville, Tenn. Easton Pa., Chemical Publishing Co., 1910. 266 pages, 8vo., cloth. Price, $2.00.

Royal Institution of Great Britain. Weekly evening meeting February 11, 1910, Electrical and Other Properties of Sand, by Charles E. S. Phillips, Esq., F.R.S.E., M.R.I.; April 15, 1910, The Chemical Significance of Crystal Structure, by Professor William J. Pope, M.A., F.R.S.; April 22, 1910, The Telegraphy of Photographs, Wireless and by Wire, by T. Thorne Baker, Esq., F.C.S., A.I.E.E. Three pamphlets, 8vo.

Ontario Bureau of Mines. Nineteenth annual report, 1910, vol. xix, part 1. Toronto, King's Printer, 1910. 245 pages, illustrations, plates, maps, 8vo.

Production of Coal and Coke in Canada During the Calendar Year 1909. By John McLeish, B.A., chief of the division of mineral resources and statistics. Ottawa, Government Printing Bureau, 1910.

Centenario de la Republica Argentina. Exposicion internacional de ferrocarriles y transportes terrestres. Catalogo oficial. Buenos Aires, 1910. 270 pages, 8vo.

Königliches Materialprüfungsamt der Technischen Hochschule zu Berlin. Bericht über die Tätigkeit des Amtes im Betriebsjahr, 1909. Sonderabdruck aus den Mitteilungen aus dem königlichen Materialprüfungsamt zu Gross-Lichterfelde West, 1910. 112 pages, 8vo.

Manchester Steam Users' Association, Memorandum by chief engineer for the year 1909. Manchester, 1910. 32 pages, 8vo.

U. S. Bureau of Steam Engineering. Annual report of the Chief to the Secretary of the Navy for the fiscal year, 1910. Washington, Government Printing Office, 1910. 31 pages, 8vo.

CORRESPONDENCE.

City of Bradford Education Committee.

TECHNICAL COLLEGE, BRADFORD, NOV. 21, 1910.

Principal: W. M. GARDNER, M.Sc., F.C.S.

THE EDITOR,
THE JOURNAL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA.

DEAR SIR:

In your November issue, page 367, I find a statement in an article on "Vacuum Tube Lighting" by D. M. Moore, to the following effect:

> "All the primary colors as well as their shades, are disastrously distorted by all forms of light except that from the carbon dioxide vacuum tube."

To this statement I must take entire exception, since for ten years there has been on the market in this country and Europe generally, a color-matching lamp known as the "Dalite" lamp, the joint invention of Mr. A. Dufton and myself. Many hundreds of these lamps are in use here, and in Germany, France, etc., by dyers who are accustomed to match the most difficult shades by their light. It is indeed, not too much to say that all large dyehouses on this side of the water are now using them.

I shall be glad if you will publish this in your valuable JOURNAL.

Yours faithfully,
(Signed) WALTER M. GARDNER.

Moore Light Company,
169 Malvern Street,
Newark, New Jersey.

December 3, 1910.

THE JOURNAL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA.

DEAR SIR:

I note the letter you have received from Walter M. Gardner, of Bradford, England, which refers to a statement in an article furnished by me for the November issue of the JOURNAL OF THE FRANKLIN INSTITUTE. The letter does not accurately quote from my article in that the word "disastrously" has been substituted for "seriously." However, there is no reason whatever

for changing my statement in the least. For the past quarter of a century many hundreds of various forms of artificial light have been sold, due to claims being made for them that they were suitable to be used in the matching of colors. In fact from the beginning of the electric-lighting industry workers requiring a light of proper color-values have been told that almost each new form of arc or incandescent lamp far exceeded all others in this respect. There are probably tons of printed matter making these claims to-day in this country and in Europe for various modified forms of arc and incandescent lamps, for example, Tungsten or Nernst lamps—but after giving careful attention to this matter for some years past and getting into communication in various ways with thousands of interested parties, I have yet to find a single individual who has claimed that any of these lights were entirely satisfactory.

By this it is not to be inferred that the exploiters of these various forms of light were not entirely sincere, but simply that each light was capable of satisfactorily matching certain colors, but not the whole spectrum, and secondly, because that since daylight varies in some of its colors even at the same hours of the day but under different weather conditions as much as 50 per cent. The shortcomings of all of these forms of light are most clearly shown by arranging a test that consists of rapidly throwing upon a certain piece of goods, for example, first the lighting and then either daylight or the white Moore Light.

It is an extremely fortunate scientific coincidence that the carbon dioxide used in the white Moore Light produces a spectrum which accurately duplicates this spectrum of average daylight and there has never been an instance where the color values of the white Moore Light have not given absolute and entire satisfaction. In fact, nothing further in the way of improvements in the color values of the Moore Light can be conceived. I have not yet been able to discover any large dyeing establishment or other industry dependent upon color values which operates all night except by use of the white Moore Light.

Yours truly,

(Signed) D. McFARLAN MOORE.

The Oxy-Acetylene Flame. ANON. (*Eng. Record,* lxii, 12.)—Although this flame has been found exceedingly useful for the removal of wrecked steel in many cases, yet it appears that the fears entertained that burglars might use it for attacking safes have proved practically groundless. In one case where the flame was used on a safe put in place in 1883, before oxy-acetylene was applied to such purposes, the damage done was merely of a superficial character. Modern safes are insulated with materials which resist penetration. The substance most commonly used for this insulation is a patented mixture containing Portland cement and carborundum, and although the oxy-acetylene flame can be made to fuse cement alone, it is not sufficiently powerful to penetrate the combination of the two materials mentioned. The necessity of the case led to the invention of a flame-proof insulator.

HONORS BY THE FRANKLIN INSTITUTE.

No title of nobility may be granted by the United States, according to the Constitution; but there is no law which can prevent the reward of just merit. There are various societies and institutions in this country from the Cincinnati to the Hall of Fame which confer more or less distinction upon persons living or dead. Some of these honors are for merit and some by reason of primogeniture. There are all sorts of academies, too, which confer more or less distinction by virtue of membership. But the real aristocracy of this country, so far as achievement for the substantial benefit of mankind is concerned, includes especially those who have been honored by the Franklin Institute of this city.

The Institute confers various medals, according to their foundation, upon men who have accomplished much. Scarcely anywhere is there a more meritorious recognition than goes to the man who wears a Cresson gold medal. No one has this "order" without having won it by notable achievements through which mankind has been benefited. The Nobel prizes are richer in emolument, but fundamentally not so distinctive. The Franklin Institute looks less to ethics than to achievement. Nor is it insular. Of the seven medals just granted, three go to foreigners and only two to Pennsylvanians. Nearly every one of these men is past the greatest period of activity, so that the medals come as rewards for service rather than as incentives.

Of the many institutions which bear Franklin's name none has accomplished more in the past eighty-five years than the Franklin Institute. Indeed, there is not a single American society of that kind which stands so high throughout the world. It is, therefore, humiliating that the Institute should be housed in such poor fashion, that its efforts to get new quarters should have so far come to naught and that its assets are so meagre. The stimulus and the instruction given by this institute have made, directly or indirectly, many American millionaires, and it is much to be regretted that these have not endowed the Institute sufficiently to establish it in fine modern headquarters and to provide a fund for increasing its activities, which are always solely for the practical uplift of society.—Editorial, *Evening Bulletin*, Philadelphia, December 6, 1910.

CURRENT TOPICS.

Decomposition and Weathering Phenomena in Young Volcanic Rocks. C. GAGEL. (*Centr. Min.*, 1910, 225.)—Through chemical analysis of trachydolerites and phonolites from Madeira and Teneriffe, and their decomposition products, the progress of kaolinization in the rocks is shown. This kaolinization is ascribed to the action of carbon dioxide. Other varieties of decomposition in Teneriffe in which no kaolin was formed are ascribed to contact action, or regional influences. Certain feldspar residues are assumed to be of a colloidal nature.

To Preserve Rubber Tubing. (*Pharmac. Journal*—from *Amer. Mach.*, xxxiii, 34.)—Immerse the rubber tubing in a mixture of 1 part ammonia and 2 parts water for a time varying from a few minutes to half an hour or an hour, until the original elasticity is regained; or frequently wash the articles in slightly alkaline water. Keeping the goods in air-tight vessels will preserve them for a long time; and so will well closed tin boxes containing quicklime and ammonium carbonate.

The Composition of Gas in Very Hot Flames. (*La Nature*, No. 1948, 129.)—The products of combustion of gases in very hot flames are not always identical with those generally met with. Thus it has been shown that in the presence of an excess of oxygen the combustion of carbon monoxide gives ozone; under the same conditions the hydrogen flame also contains ozone and a little nitrous oxide; and further the acetylene flame contains almost 4 per cent. of this same nitrous oxide. The temperatures attained during the combustion of these gases, under the above conditions, are exceedingly high, about 2600° C. for carbon monoxide, 2800° C. for hydrogen, and 3000° C. for acetylene.

Aluminum-Bronze. E. S. SPERRY. (*Brass World*, vi, 3.)—Aluminum alloys with copper in all proportions and produces homogeneous mixtures. When the aluminum goes beyond 10 per cent. the bronze gets brittle, and a 12 per cent. mixture is hard enough for hard dies. For sand casting the 10 per cent. alloy is generally used, as it is hard and tough and has the properties of a strong metal. The great difficulty in casting aluminum-bronze is its oxidation when melted. It must be poured without agitation, to avoid dross. Dross formed in melting may be skimmed off, but that which is formed while pouring enters the casting. Another difficulty is the shrinkage. By the use of sufficiently large risers, and the avoidance of sharp corners in the casting, and an ample

gate, this shrinkage may be overcome. The toughness of aluminum-bronze is greater than that of any metal except steel. It works hot better than copper, as it is softer at a red heat, and it is not black-short like copper and zinc alloys.

The Spectrum of Radium Emanation. H. E. WATSON. (*Proc. Roy. Soc. London,* A., lxxxiii, 50.)—Royds, in a criticism of Cameron and Ramsay's spectrum, stated that this included Xe lines, on which account this research was undertaken. The gas was purified by Ramsay, being sparked in the presence of fused KOH, frozen in liquid air, and the excess of hydrogen pumped off. Photographs were taken with a prism spectrograph and with a grating, and compared with an Xe spark spectrum. The author concludes that ten of Collie and Ramsay's lines were due to the emanation, and the remainder were mercury lines. The identity of Xe lines in Cameron and Ramsay's spectrum is undoubted, but could not be due to accidental contamination, as Royds suggested. No Xe ever entered Ramsay's private laboratory, and contamination by air would have introduced Kr lines also. Apparently the emanation has broken down into Xe, possibly Cu acted as the transforming agent.

To Restore Their Phosphorescent Properties to Alkaline Earth Sulphides. D. GERNEZ. (*Ann. chim. phys.,* xx, 166.)—The sulphides of barium, strontium, and calcium lose their phosphorescent properties after long exposure. Exposure to light, darkness, heat, or moisture has but little restorative effect, but when a current of dry hydrogen is passed over them, they phosphoresce as brilliantly as when first made. While hydrogen is reacting, water vapor is set free accompanied by a series of small explosions.

The Volatile Matter of Coal.—The first bulletin to be issued by the new Federal Bureau of Mines will bear the above title. The authors, Horace C. Potter and F. K. Ovitz, conducted their investigations at the Pittsburg station while it was under the Technologic Branch of the Geological Survey, the work being a continuation of the fuel investigations begun several years ago at the Louisiana Purchase Exposition, St. Louis, Mo. The results obtained at that plant showed that the work of determining the fuel values of the coals and lignites in the United States with a view to increasing efficiency in their utilization would be incomplete if it did not include systematic physical and chemical researches into the processes of combustion. Hence in their later investigations the authors carried on such researches, concentrating attention on those lines of inquiry which promised results of greatest economic importance. This bulletin is therefore a report on an investigation of the volatile matter in several typical coals—its composition and amount at different temperatures of volatilization.

Quoted directly the authors say: "The investigation has already

shown that the volatile content of different coals differs greatly in character. The volatile matter of the younger coals found in the West includes a large proportion of carbon dioxide, carbon monoxide, and water, and a correspondingly small proportion of hydrocarbons and tarry vapors. The older bituminous coals of the Appalachian region yield volatile matter containing large amounts of tarry vapors and hydrocarbons, difficult to burn completely without considerable excess of air and a high temperature. Coal of the Western type, moreover, gives up its volatile matter more easily at moderate and low temperatures than that of the other type. The volatile matter produced at medium and low temperatures is rich in higher hydrocarbons of the methane type, such as ethane and propane, which contain a larger portion of carbon than is present in methane.

"These facts help to explain the difficulty of burning Pittsburg coal, for example, without smoke, the low efficiency usually obtained in burning high-volatile Western coals, the advantage of a preheated auxiliary air supply introduced over a fuel bed, and the advantage of a furnace and boiler setting adapted to the type of fuel used. They bear directly also on the question of steaming 'capacity' of coal for locomotives, the designing and operation of gas producers for high-volatile fuels, and the operation of coke ovens and gas retorts.

"The results show further that certain bituminous coals of the interior and Rocky Mountain provinces give promise of good yields of by-products of coking, notably ammonia and high candlepower gas, comparing favorably in these respects with the high-grade coking coals of the eastern province.

"They show also that inert, noncombustible material is present in the volatile products of different kinds of coal to an extent ranging from 1 to 15 per cent. of the coal."

The publication will be of interest to fuel engineers, designers and builders of gas producers, gas and coke manufacturers, superintendents of power plants, railway master mechanics and those engaged in the suppression of smoke. Copies of the bulletin may be obtained by applying to the Director of the Bureau of Mines, Washington, D. C.

Department of Non-ferrous Metallurgy. (*Times, Eng. Suppl.*, Oct. 26, 1910.)—Prof. J. O. Arnold in his presidential address to the Electrometallurgical Society of Sheffield, England, stated that the University contemplated the establishment of a department for the study of non-ferrous metals. The University authorities had already provided a Kjellin non-ferrous crucible, with the aid of which a series of tests would be made as to the relative merits of coke and electric melting of base metal. The University was already in a position to experiment on the electric melting of brasses, bronzes and German silver.

Positive Band Spectrum of Nitrogen. E. ANGERER. (*Ann. de Phys.*, xxxii, 3.)—A complete article on the positive band spectrum of nitrogen and the changes it undergoes with decrease in temperature. Various forms of vacuum tubes were employed both with and without electrodes, and great care was used to prepare a pure nitrogen. The changes which occur are given in detail, and the wave-lengths of the lines.

Helium in the Atmosphere. A. PIUTTI. (*Le Radium*, vii, 142.)—The author describes a sensitive method of estimating the amount of helium in the atmosphere and in minerals. The principle depends upon the absorption of the gases other than helium by cocoanut charcoal immersed in liquid air. The helium is estimated by the intensity of the various helium lines in a spectroscope placed along the prolongation of a Plucker tube. He succeeded in tracing the presence of helium in 3.5 c.c. of air at Naples. He also gives measurements of helium given off when different Zircons are heated, and compares these measurements with their radio-activity and density, of nineteen Zircons examined; that from Vesuvius contained the least helium relative to its radio-activity, and that from Renfrew (Canada) the most.

Portability of the Weston Cell. H. TINSLEY. (*Electrician*, lxv, 568.)—To prevent the ingredients of a cell being displaced in transit, drum-heads of cork and linen are placed over the solid chemicals. Cells set up in this way do not appear to have their e.m.f. affected by this linen screen, and as this becomes at once impregnated with solution, its resistance is kept low. These cells appear to have a very uniform resistance of about 700 ohms.

Chemical Reactions and Ionizations. M. G. REBOUL. (*Mon. scientifique*, xxiv, 826.)—Alkaline metals, which oxidize in damp air, emit charges of both signs, with negative charges preponderating. If two perfectly insulated vessels, one containing ammonia and the other hydrochloric acid, are placed between the armatures of a condenser in such a way that the field becomes active at the moment of reaction, when ammoniam chloride is formed, a current passes between the two armatures. When nitrogen di-oxide reacts with oxygen in a platinum apparatus, the charges disappear almost entirely, they reappear if damp copper is introduced into the apparatus; these charges proceed from an action on the electrodes.

On the Relative Duration of Calcium Rays in the Spark of Self-induction. M. G. A. HEMSALECH. (*Comptes rendus*, cli, 220.)—In the consideration of arc rays it is noticed, as has been previously observed of the rays of iron, that their duration is nearly proportional to their intensity. The duration of the spark

rays shows a more rapid abatement of the atomic vibrations to which they are due, than the arc rays. Even the most intense rays, *H* and *K*, do not last as long as some weaker arc rays. The ray 3706, with an intensity of 10, has the shortest duration of all the rays. The examination of calcium, containing traces of Sr, Mg, Al, and Mn, gives these results: Always distinguishing between arc rays and spark rays, and granting that the duration of a ray depends on its intensity, the duration of strontium rays is far greater than that of calcium rays. On the other hand, the rays of magnesium are relatively shorter than the corresponding rays of calcium. The two aluminum rays between *H* and *K* have almost normal duration, while the triple rays of manganese show a greater duration than the equally intense calcium rays. It follows from these data that the observation of the relative duration of spectral rays might, in certain conditions, give useful indications in the analysis of substances containing unknown impurities.

Removal of Paraffin, Vaseline, etc. C. BENEDICKS. (*Phys. Zeitschr.*, xi, 254.)—Paraffin and vaseline, etc., can be removed by washing with condensing alcohol vapor. Thus by inserting a beaker which has contained paraffin over another containing a little alcohol and placed on a water bath, the paraffin is removed. This method can be applied to the removal of grease from the fractured surface of steel, or from articles to be silvered and so on.

A Carthaginian Lamp. M. EUGÈNE COLLIN. (*Mon. scientifique*, xxiv, 826.)—The microscopical examination of the wick fibres, after bleaching with permanganate in sulphuric solution and then treating with bisulphite, shows that this wick consists of flax fibre.

Composition of Greek Vases. W. FOSTER. (*J. Amer. Chem. Soc.*, xxxii, 1259.)—Experiments show that the black glaze of the Attic styles of vase is due to ferrous iron probably as silicate, while the red glaze of the Mycenaean style is probably due to ferric iron. These views are supported by synthetic experiments. The complete analyses of fragments of vases show that the Mycenaean pottery is much poorer in silica and richer in lime, and therefore more fusible than the Attic.

Metallic Strontium. B. L. GLASCOCK. (*J. Amer. Chem. Soc.*, xxxii, 1222.)—This metal was obtained by fusing pure strontium chloride in a hemispherical iron cathode vessel 25 cm. in diameter, with walls 0.6 cm. thick, with a carbon anode 8 cm. x 8 cm. This allowed a low anode current density and avoided overheating. With a current of 125 ampères and 40 volts for 7 hours, 76 Gm. of metal were removed in small lumps up to 3 Gm. in weight. The

metal is removed from the mixture by crushing on an iron plate and then sifting away the chloride. Analysis showed it to contain about 98 per cent. of metallic strontium, which is a light metal, with a silvery lustre when cut, gradually becoming yellow and finally white and non-lustrous. It is softer than calcium and can be cut with a knife. It alloys with iron. Hydrogen and nitrogen unite with the heated metal. The specific gravity is 2.55 and the specific heat 0.0742, corresponding to an atomic heat of 6.5. The iron alloy is rather hard, and decomposes water. This alloy contained 23 per cent. of strontium.

Radiation Pyrometers.—The Cambridge Scientific Instrument Co., Ltd., has patented a radiation perometer which consists of a closed tube, in one end of which a sensitive element is arranged with a mirror, lens or diaphragm so that the radiation from the other end, which is exposed to the temperature to be measured, may be recorded. Focussing is thus avoided, and since true "black body" conditions are established the readings are independent of the nature of the surface of the hot end of the tube.

Power Gas and its Development. J. S. S. BRAME. (*Chem. Trade J.*, xlvii, 376.)—The introduction of power gas has made considerable economy possible in the use of fuel resources. Blast-furnace and coke-oven gas, previously wasted, can be utilized and the replacement of steam power by gas power would diminish the annual consumption of coal for power by 9 million tons, or 20 per cent., in England. Power gas can be generated from heat or other poor fuels not suitable for raising steam. There are 140 million acres of peat bog in Europe. For small powers up to 30 h.p. he recommends the use of coal gas rather than a gas plant; from 30 to 250 h.p. a suction gas plant is recommended; and for greater power, a pressure gas plant. Recent developments are the use of the engine exhaust in place of steam in the producer, and the abolition of the gas holder in pressure gas plants, the production being controlled by fans driven by the engine.

Value of Waste Yeast. G. GRAF. (*Allgem. Zeit. Bierbrau*, xxxviii, 372.)—Waste brewery yeast is but little utilized and great quantities of potentially valuable food material are annually wasted. Yeast has been proved to be a suitable addition to cattle food when supplied in quantities of 1 pound per 100 pounds of live weight. Cakes of compressed yeast and spent hops are readily eaten by cattle and should provide a cheap and generally used food-stuff. Such food could be prepared at a far from prohibitive cost. The waste yeast is first washed, drained and pressed to remove the excess of moisture; it is then plasmolysed by adding 1 to 2 per cent. of common salt and dried. The compressed cakes

of yeast and spent hops have the following composition: water 10, proteins 55, non-nitrogenous extractives and cellulose 24.2, ash 7.8, and fat 3 per cent. They should be worth three dollars per hundred weight.

Waterproofing Filter Beds and Reservoirs. (*Eng. Record*, lxii, 16.)—Mr. H. Ashley, Engineer of the Portsmouth (England) Water Co.'s plant at Farlington, reports that an area of seven acres of floors and walls of the filter beds and reservoirs were waterproofed by two coats of cement plastering. The first coat was three-quarters of an inch thick and the second one-quarter of an inch. The result was very successful, as careful tests frequently repeated, disclosed no leakage whatever.

Solubility of Finely Divided Gold in Potassium Ferrocyanide Solution. E. BEUTEL. (*Monats. Chemie*, xxxi, 887.)—Finely divided gold dissolves slowly in potassium ferrocyanide solution at the ordinary temperature, and forms a distinctly alkaline solution; solution is very slow even at boiling point. Apparently potassium aurocyanide is first formed, and the liberated ferrous ions are oxidized by the atmosphere to ferric hydroxide, which is precipitated, in amount corresponding to the amount of gold dissolved. Prolonged action of a strong solution of potassium ferrocyanide seems to give ultimately potassium auricyanide.

Problems in Soil Fertility. J. G. LIPMAN. (*J. Agric. Sci.*, iii, 297.)—By growing oats in the inner, and peas in the outer of two concentric pots, the inner pot being very porous in one case and glazed in the other. The beneficial effect of the legume on the growth of the grain was clearly shown when the inner pot was porous. As no nitrogen was supplied, it was evident that soluble nitrogen compounds were passing from the peas to the oats through the unglazed inner pot. This device might be applied to the study of other problems as to the action of one crop on the growth of another.

Impermeability of Gelatin Increased. A. and L. LUMIÈRE and A. SEYEWETZ. (*Photo. Jour.*, l, 34.)—From experiments it is concluded that substances which render gelatin insoluble, also decrease its permeability, measured by the amount of water absorbed in a given time. The substances used are placed in the order of their power of decreasing permeability; formalin, sodium-quinonesulphonate, quinone, chrome-alum, potassium-alum. The last is not a true insolubilizing agent as it only raises the melting point of gelatin, and is weaker in its action than the other four. Sodium-quinonesulphonate and quinone, although they stain the gelatin and are not so powerful as formalin, are preferable in photography.

since the contraction induced by formalin separates the gelatin from the glass. Much more quinone and sodium-quinonesulphonate can be used than formalin without decreasing the fluidity of the resulting gelatin solutions.

Uranium Ore in Mexico. (*L'Ind. Chimica*, x, 270.)—Mr. W. Niven discovered a new mineral in the Guerrero district of Mexico which was a hydrophosphate of uranium and copper. This mineral, which is called torbernite has a slight action on a photographic plate in the dark. Experiments are being made to ascertain the suitability of the mineral as a raw material for the manufacture of radium salts.

Recent Hydro-electric Practice in Switzerland. PROF. W. F. DURAND. (*Eng. Record*, lxii, 20.)—A very interesting illustrated article on hydro-electric power plants in different parts of Switzerland which will amply repay perusal.

Transference of Heat. W. MUSSELT. (*Eng. Record*, lxii, 20.)—Mr. Musselt states that heat transfer through the walls of a pipe at any point is independent of the velocity, density, and specific heat of the fluid in the pipe, but is directly proportional to the coefficient of heat conduction and inversely proportional to the diameter of the pipe.

Metallic Coatings. (*Eng. Record*, lxii, 20.)—Mr. M. U. Schoop has produced metallic coatings on cloth, paper, wood, and metal by a spraying process. The fused metal is discharged through a fine orifice and turned into a fine spray by a current of air or gas blown across the jet at a high pressure at a right angle. The minute particles of metal are so cooled by the air or gas jet that they do not ignite the coated material.

Silica Discovered in Canada. (*Oil, Paint and Drug Reporter*, Oct. 3, 1910.)—An apparently unlimited quantity of silica, free from iron, has been found at St. Anne's, Manitoba. It was at a depth of 194 feet and was driven through for 14 feet without finding the bottom of the deposit. A similar discovery was made on a neighboring farm.

Pyrophoric Alloys and the Modern "Flint and Steel." (*La Nature*, No. 1952.)—These "flint and steels," like those of our forefathers, produce sparks by the blow of a piece of steel on a special stone. But this stone is not the old flint of long ago, and the sparks are so hot that at the first blow they will kindle tinder or a match soaked in benzine or alcohol.

This discovery is due to Auer, who found the necessary qualities

in an alloy of iron and cerium. It has been known for some time that other metals than iron would give pyrophoric sparks when struck. M. Chesneau, in 1896, showed that uranium gave sparks that would kindle a mixture of inflammable gases. The pyrophoric qualities of the cerium family of metals have long been known. But alone they are too soft and light, and Auer conceived the idea of alloying them with iron.

Electric Steel Refining. (*Eng. Record,* lxii, 20.)—The U. S. Steel Corporation has been paying attention to a number of methods of increasing the quality of some of its products, and to this end has acquired complete control of the Héroult patents in America. The electric refining experiments at South Chicago, on steel produced in a Bessemer converter, were intended to improve metal for rails and axles, and thus compete with the wholly different Gayley methods. These improvements, due to Mr. W. R. Walker, are said to have decreased the cost of the process. Enough has been said to justify a belief that real progress has been made in the art of producing better steel in large quantities at reasonable prices.

Guages Used in Testing Materials. H. F. MOORE. (*Amer. Mach.,* xxxiii, 44.)—A valuable description of guages used at the University of Illinois for testing small strains over various parts of the specimen under test. Ames dial guages are used to test large specimens. These tests include those for tension, compression, deflection and fibre strain on wood, steel, concrete, and terra cotta. An ingenious method of calibrating the guages is described.

The Unstable Equilibrium of the Balloon. TECUMSEH SWIFT. (*Amer. Mach.,* xxxiii, 44.)—An interesting article, endeavoring to point out out how little is really known of the necessities of aviation, and how much is left to chance and "rule of thumb" work. "The dirigible balloon is entirely a balloon and only slightly a 'dirigible.' It must wait upon the fickle winds and can not oppose them."

Powder Thawing Device. (*Eng. Record,* lxii, 17.—From the *Mining and Scientific Press.*)—This is constructed by boring two 1¼ in. holes in the side of a barrel, 6 in. from each end, in the same vertical line, fitting a 4 or 5 ft. length of pipe into each of these holes and connecting the outer ends of the pipes with another length. A grating or rack is fixed in the barrel, on which a 5 gallon oil can is placed containing the powder to be thawed. The open top of the can is just below the upper rim of the barrel. The barrel is filled with water to just above the upper pipe level and a fire lighted beneath the lower pipe near where the vertical riser connects it with the upper horizontal pipe, so that the heated water

circulates. The powder in the can is said to thaw gradually and safely. The barrel and can are fitted with separate covers. The can should be cleaned after each operation, to remove any traces of exuded nitroglycerin.

Preparation of Hydrogen by Silicium. (*La Nature*, No. 1952.)—The development of aeronautics, especially from the military point of view, has made the manufacture of hydrogen of great importance. A German society, the Consortium of electrochemical industry of Nuremburg, has patented a process which appears to give excellent results. By this process a solution of sodium hydroxide, mixed with a little calcium oxide (lime) is decomposed by silicium prepared in an electric furnace. The gas thus obtained is very pure; 2.2 kg. of silicium produces a cubic metre of gas.

Ventilating Tunnels and other Workings by Water Power. (*Eng. Record*, lxii, 15.)—Taken from "Mining and Scientific Press." This method consists of allowing a stream of water to fall through a vertical passage whose lower terminal is in a closed chamber and beneath a constant water level. The water escapes through a submerged orifice as fast as it enters, and the air carried down by the stream accumulates in the space above the water level, developing the pressure which forces it through mains to the desired point. The upper end of the vertical passage is covered with a screen so as to break up the entering stream. A fall through a 12 in. pipe, 30 ft. long, is said to have provided an abundant supply at a distance of 600 ft. from the air chamber.

Copper Sulphate to Prevent Algæ. (*Eng. Record*, lxii, 15.)—Four of the reservoirs of the Albany water works were treated with copper sulphate before the warm weather. Two were treated four times during the season, one three times, and the other twice. The maximum amount used during any one operation was 0.32 parts per million and the minimum quantity 0.1 parts per million. Mr. H. J. Deutschbein, Superintendent of the water bureau, accounts for the fact that no complaints regarding algæ were received during the year, to the early start of this treatment and the constant watching of the aquatic growths. The reservoirs are supplied with filtered water from the Hudson River.

Some Common Defects in Alloys. C. H. DESCH. (*Inst. of Metals*, Sept., 1910.)—The common defects of non-ferrous alloys are here classified, and the causes and means of detecting them are discussed, and the conditions under which they occur. The defects are (1) sponginess, due to the enclosure of gas; (2) brittleness or weakness, due to the presence of oxides or other drossy matter, or intercrystalline metal or eutectic alloy; (3) defects due to inequalities of composition, caused by imperfect

mixing of the ingredients, separation by gravity during solidification, or segregation in the mould; (4) excessively coarse structure, due to casting at too high a temperature; (5) defects due to wrong thermal treatment, such as quenching from a high temperature, heating at too high a temperature or for too long a time during annealing, "burning" in the case of alloys of copper and zinc, or unequal thermal treatment of different parts of the same casting or forging; (6) defects due to molecular change other than that produced by mechanical stress; (7) shrinkage cracks; (8) defects due to molecular change produced by mechanical deformation, viz., brittleness of cold-worked metals, chilling cracks, and cracking during hot working; (9) corrosion; (10) erosion.

Gas Evolution and Capacity of the Lead Accumulator. F. STREINTZ. (*Zeit. Elektrochem.*, xvi, 747.)—A complete investigation of the gas evolution (compared with a copper voltameter) and of the changes in potential of the electrodes in an accumulator lends to the conclusion that hydrogen may be occluded by the reduced negative plate in charging. Oxygen absorption also takes place in the positive plate, but this is due to its penetration to the metal and formation of more peroxide. The discharge data show that the sharp fall in potential may be due to the exhaustion of the negative or of the positive plate. The former is the more usual case in actual practice, but the latter may occur either (1) in an initial discharge when the positive plate is not completely formed; or (2) when the charging has been so carried out that the negative plate has been enabled to occlude considerable quantities of hydrogen. In the latter of these cases the capacity of the cell is of course found to be higher than usual.

Sparking at the Electrodes. A. KAILAN. (*Zeit. anorg. Chemie.*, lxviii, 141.)—The anodic disturbances which are observed occasionally in the electrolysis of fused lithium chloride and other salts have been investigated. The author does not support the view that the phenomenon is caused by the formation of a sub-chloride in the melt, or by the appearance of a film of silicic acid (from the vessel) on the cathode. The electrolysis proceeds normally with a higher temperature and he suggests that the cause is a change in the viscosity of the melt. This view is supported by the fact that under similar conditions the critical temperature is 100° higher for pure lithium chloride than for a 50 per cent. mixture of lithium and potassium chlorides. The sparking is produced quite readily with a platinum (instead of a carbon) anode, while there is no disturbance at all with an alternating current. While the sparking lasts it is noticed that the apparent resistance of the cell decreases with increasing e.m.f. A mixture of 1 part lithium bromide with 6 parts lithium chloride does not spark nearly so

easily as pure chloride nor as a mixture of lithium and potassium chlorides. Oscillographic reproduction of the curve of current strength during the disturbance shows that when the anode is sufficiently deeply immersed, there are no great fluctuations with an e.m.f. of 110 volts and a resistance of 19 ohms. From these facts the author prefers a purely physical explanation of the phenomenon.

Cold Vulcanization. H. E. POTTS. (*Zeit. chem. Ind. Koll.*, vii, 111.)—Bysow's explanation of the adsorption of sulphur-chloride by rubber is insufficient. Bysow measured the surface tension air-solution. The determining factor in adsorption on Gibbs' theory, is the variation in the tension rubber solution. This latter is unknown. In an editorial note W. Ostwald agrees, but suggests the two tensions may run in parallel series. He notes that Traube's theory of attraction pressures is open to the same objection.

Electric Steel Refining. D. F. CAMPBELL. (*Iron and Steel Inst.*, Sept., 1910.)—Describes the great possibilities of electrical refining in conjunction with the various steel processes. The increase in the capacity of the Talbot and other open-hearth furnaces is very important, because the expensive processes of desulphurization and attaining a teeming heat can be most profitably carried out by transferring a portion of the charge to the electric furnace and making up again in the main furnace with raw material. It will be cheaper to add an electric furnace to a Bessemer plant than to replace it by open-hearth furnaces. The following are the most desirable features of design: 1. The best open-hearth design, with homogeneous solid bottom and bands free from imbedded electrodes. 2. All electrical mechanism, generators, transformers, etc., should be separate from the furnace. 3. Maintain a high power factor. 4. The roof should be protected from direct radiation by the electrodes and the intensely heated area of slag should be as large as possible. 5. The heat should be applied to the slag, which must be kept very fluid and hotter than the steel.

The Quality of Boiler Tubes. (*Iron Age*, lxxxvi, 16.)—At the Convention of the American Boiler Manufacturers' Association, Mr. Charles S. Blake, Secretary of the Hartford Steam Boiler Inspection and Insurance Co., attacked the quality of boiler tubes. He stated that "tube failures are woefully common. Twenty-five years ago the average steam pressure ran from 80 to 100 lbs., and the tubes in use at that time were identical in thickness, except in specific instances, with those in use to-day for pressures of 150 lbs. to 175 lbs., and the average quality has not improved, so that the standard commercial tube of to-day is no better than, if as good, as the tube of those days."

Mr. Blake's assertions are evidently based upon the findings of the company's inspectors. If these reports are made without thorough investigation, the manufacturers of boiler-tubes are being grievously wronged. If the facts are as stated, the tube manufacturers should take steps to bring the quality of their product up to the requirement of the times.

Mordant Dyestuffs. E. NOELTING. (*Chem. Zeit.*, xxxiv, 977.)—The author states that when a dyestuff, particularly one belonging to the anthroquinone series, contains a hydroxyl and an amino-group in the ortho-position with respect to one another, the substance has mordant dyeing properties. Mordant dyestuffs are sometimes formed when the two groups are in the para-position respectively, but the affinity for the fibre is not so great in this case. It is remarkable that all amino-hydroxy-compounds give strong colors on a copper mordant.

Grahamite, a Solid Native Bitumen. C. RICHARDSON. (*J. Amer. Chem. Soc.*, xxxii, 1032.)—Grahamite was discovered in West Virginia, in about 1860, but there is considerable confusion in literature as to its distinction from albertite and gilsonite and to a certain extent from manjak. It may be described as a brittle, solid native bitumen, generally pure, but at times mixed with adventitious mineral matter; characterized when pure by a peculiar schistose fracture, known as "hackly." It does not melt, but intumesces; it is soluble in carbon bisulphide and to a small extent in light naphtha and yields a high percentage of coke. It closely resembles the "asphaltenes."

European and American Wood-block Pavements. CLIFFORD RICHARDSON. (*Eng. Record*, lxii, 14.)—This interesting communication compares wood block pavements as laid down in Paris, London and New York. The weak points of the American system of constructing wood-block pavements are,—lack of depth to the block, extravagance in the matter of saturation, neglect to use a waterproof filler, and the use of a mortar bed instead of a smooth-floated concrete foundation.

Asbestos in the United States.—The United States has for years led all other countries in the manufacture of asbestos goods, but until recently all the raw asbestos used has been imported from Canada, where there are nineteen quarries and mills, having a capacity of 8250 tons of rock a day and employing in summer more than 3000 persons.

A feature of the asbestos industry of 1909 was a combination of Canadian producers in the Amalgamated Asbestos Corporation (Ltd.) and the formation of the International Asbestos Association,

an organization including mine owners in Canada and manufacturers in the United States.

No asbestos of the higher grade (serpentine asbestos, or chrysotile) was mined in the United States until 1908, but in that year Vermont produced some chrysotile and in 1909 mined a larger quantity, amounting to nearly one-twentieth of the Canadian output. Chrysotile asbestos has been mined in small quantities in Wyoming during the present year.

Asbestos is insoluble in acids and incombustible, is a poor conductor of heat and electricity, and is not affected by dampness, so that it is applied to many purposes. It is used for building material, pipe coverings, shingles, insulating tapes and boards, fireproof ropes and curtains, packing for fireproof safes, and packing for steam engines, as well as in paint and cement.

The United States Geological Survey has just published a report on the production of asbestos in 1909, by J. S. Diller, showing the production, imports, prices, and trade conditions during the year as well as the foreign production and trade conditions. The report contains also notes on the known asbestos deposits of the United States.

In 1909 the production of asbestos in Vermont was 200 per cent. and that of Georgia about 25 per cent. more than in 1908. Mr. Diller urges that the search for chrysotile asbestos be continued among the ancient crystalline metamorphic rocks in the United States.

Electric Arc Welding. F. SCOTT ANDERSON. (*Amer. Mach.*, xxxiii, 40.)—This article is important to those requiring such welding. It points out the advances made, particularly in portable plants. It gives a series of tests comparing the efficiency of such welds with hand welds made at a forge and with the original metal. It points out the kind of electrodes necessary, the precautions to prevent burns, and that the low tension is a safeguard from shocks.

A Fourth Recalescence in Steel. PROF. J. O. ARNOLD. (*Iron Age*, lxxxvi, 16.)—From the accumulated thermal and micrographic observations of more than 20 years, the view is put forward that the fourth phase of recalescence is due to the heat evolved during the segregation of the ultimate micrographic constituents of steel, begun at Ar_2 and completed at Ar_1, during the cooling of an unsaturated steel at a moderate rate. Between the points named it is believed the Ferrite and Hardenite fall out from their state of solid solution into microscopically visible masses.

North Dakota Lignite as a Fuel for Power-plant Boilers is the title of Bulletin No. 2 recently issued by the Bureau of Mines. This bulletin describes a series of tests at the pumping plant of the United States Reclamation Service at Williston, North Dakota.

The Reclamation Service has a large project there and had installed steam boilers with furnaces designed to burn a "brown lignite" that was mined on adjacent Government land.

The furnace is of the semi-gas-producer type and has an external resemblance to the so-called Dutch oven. The most striking features in its construction are the deep-set grate and the construction of the space between the bridge wall and the end of the prolonged fire brick arch. The furnace is designed to work on the gas-producer principle. The solid fuel is gasified on the grate and the gas passes through the space under the arch into the combustion chamber where most of the gaseous combustible burns.

The results of the tests on the lignite show that this fuel, though generally considered unsatisfactory, may be used with fair economy under boilers that generate their full rated capacity. In fact, when the number of heat units available is considered, the results compare favorably with those of better grades of fuel.

The tests are deemed important because the lignite deposits of the Northwest are so extensive and the distance of the region from other coal fields is so great that a large portion of the United States, including parts of North Dakota, South Dakota and Montana, may be greatly benefited by any improvements in the methods of utilizing this local fuel supply. The lignite in this field is low in heating value, some of it containing nearly 45 per cent. of its weight in moisture, and it is difficult to burn in the furnaces commonly used for the better grades of coal, but the tests have shown the possibility of designing suitable furnaces for burning it profitably.

The tests were conducted by the Technologic Branch of the Geological Survey which is now a part of the Bureau of Mines.

The Compass for Hardening Heats. GEORGE COLES. (*Amer. Mach.*, xxxiii, 39.)—It is stated that the proper heat for hardening carbon steel is indicated by its loss of magnetism, so that if a tool be suspended in the furnace from a magnet, it will drop at the critical moment that it reaches the correct heat for hardening. Mr. Coles says he can replace the magnet by a compass, and as soon as the magnetism in the tool ceases to affect the compass, the proper temperature is attained. The higher the content of carbon in the steel, the lower the temperature at which it will harden.

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